Model Intercomparison of AeroCom A and B simulations

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Outline of the talk

- Introduction
- AeroCom B emissions
- Exp A and B + Load
  + Residence times
  + Particle sizes
- Sink process analysis
- Spatial distributions
- Conclusions, Outlook

AeroCom

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GOALS

- Compare an **ensemble** of **global aerosol** models
- Eliminate weak components
- Reduce uncertainty in simulated radiative forcing

STRATEGY

- Multi-model evaluation with **observations**
  - From the surface (e.g., AERONET, IMPROVE, EMEP, GAW)
  - Vertical profiles (EARLINET)
  - From satellites (MODIS, AVHHR, TOMS, POLDER, MISR,...)
- Analyze and improve critical **parameters** and **processes**

BASIS

Experiment A	– models as they are	17
Experiment B	– harmonized sources y 2000	12
Experiment PRE	– harmonized sources y 1750	9
Experiment IND	- indirect effect	

http://nansen.ipsl.jussieu.fr/AEROCOM

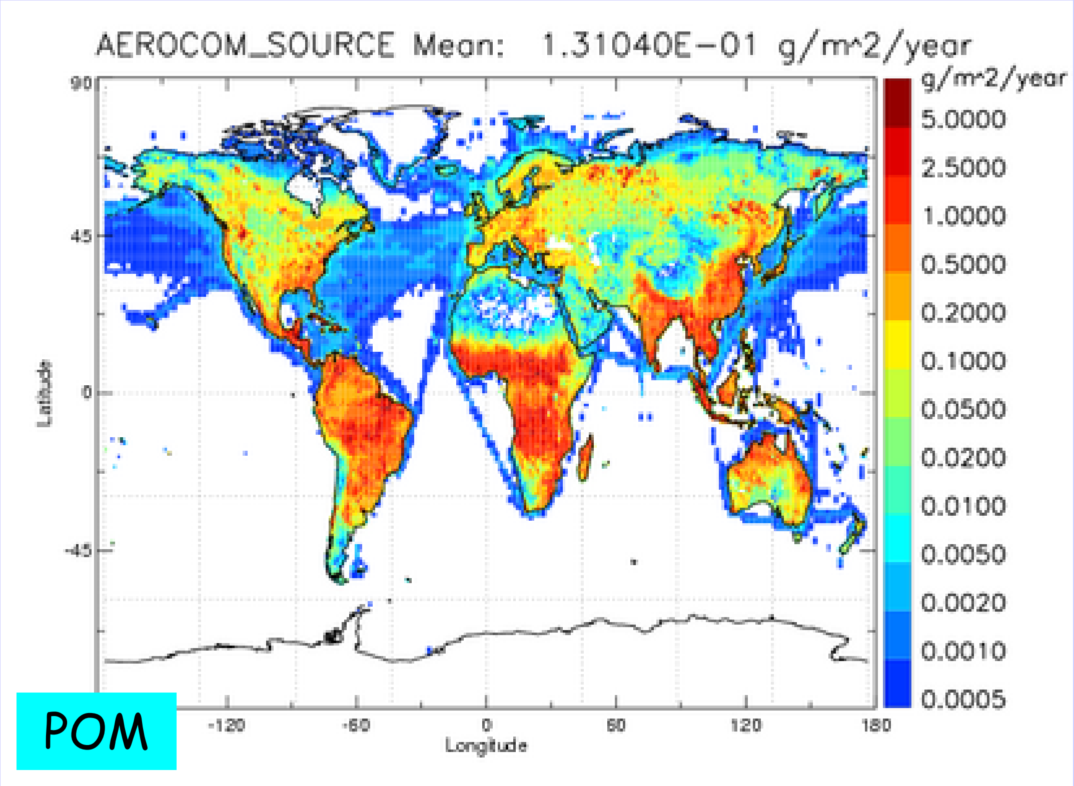
Model	Global model	Horizont. Resolution (x y) (lon lat)	Vertical Resolution (# of levels) (type)	Aerosol Module	number of bins or modes	aerosol mixing	Aerosol dynamics
ARQM	**GCM Canadian GCMIII**	128x64 2.81°x2.81°	32 sigma-p	bin	**12** all internally mixed	internal	Nucl., Coag., Condensation Thermodynamics
DLR	**GCM ECHAM4**	96x48 3.75°x3.75°	19 sigma	modal MN	**2** (B: 3) nucl+acc(B: +coa)	internal	Nucl., Coag., Condensation Thermodynamics
GISS	GCM modelE	46x72 5°x4°	20 sigma	bin	**13** 2 SS, 4 DU, 1BC, 1POM, 1SO4, 4 DU/SO4	external	aging of BC and POM hetero DU
GOCART	CTM GOCART 3.15b	144x91 2.5°x2.0°	30 sigma	modal M	**17 bins- 5 modes** 8 DU, 4 SS, 2 BC, 2POM, 1 SO4	external	aging of BC and POM
KYU	GCM CCSR/NIES/FRSGC GCM / SPRINTARS /	320x160 1.1°x1.1°	20 sigma	bin, modal mic	**17** 10 DU, 4 SS, 1 BC, 1 BCPOM, 1 SO4	external partly internal for BC/ POM	none
LSCE	GCM LMDzT 3.3	96x72 3.75°x2.5°	19 sigma	modal MN	**5** acc. sol+insol, coa sol+insol, sup.coa sol	external mixture of internally mixed modes	aging of BC and POM
LOA	GCM LMDzT 3.3	96x72 3.75°x2.5°	19 sigma	bin	**16** 2 DU, 11 SS, 2 BC, 2POM, 1 SO4	external	aging of BC and POM
MATCH	CTM MATCH v 4.2	192x94 1.9°x1.9°	28 sigma-p	bin	**8** 4DU, 1SS,1 BC, 1POM, 1SO4	external	aging of BC and POM
MPI HAM	GCM ECHAM5.2	192x96 1.8°x1.8°	31 sigma-p	modal MN	**7**	external mixture of internally mixed modes	Nucl., Coag., Condensation Thermodynamics
MOZGN	CTM MOZART v2.5	192x96 1.9°x1.9°	28 sigma -p	bin	**12** 1SU, 1OC, 1BC,5 DU, 4 SS	external	aging of BC and POM
PNNL	GCM MIRAGE 2 / derived from NCAR CAM2.0	144x91 2.5°x2.0°	24 sigma-p	modal MN	**16** ait. acc. coa. DU, coa. SS, interstit + act. each	external mixture of internally mixed modes	Nucl., Coag., Cond. Thermodyn. Cloud Processing
TM5	CTM TM5	60x45 6°x4° Europe + USA 1°x1°	25 sigma-p	modal MN	**8** 3 SS, 2 DU, SOA-POM, BC, SO4	external	aging of BC
UIO_CTM	CTM OsloCTM2	128x64 2.81°x2.81°	40 sigma	bin	**20** 8 DU, 8 SS, BC, POM, bioburn BCPOM, SO4	external except biomass burning	aging of BC and POM
UIO_GCM	**GCM CCM3.2**	128x64 2.81°x2.81°	18 sigma-p	modal M/MN, bin mic	**12 modes-43 bins** 8 int modes, DU SS fix	4 external, 8 internal (from 4 prog+ 8 prescribed)	Nucl., Coag., Condensation Thermodynamics
ULAQ	**CTM ULAQ**	16x19 22.5°x10°	26 log-p	bin	**41** 7 DU, 9SS, 5 BC, 5 POM, 15 SO4	external	aging of BC and POM SO4 microphysics
UMI	CTM IMPACT	144x91 2.5°x2°	30 sigma-p	bin	**13** 3 SO4, 1POM, 1BC, 4 DU, 4SS	external	none

Exp B emissions

AeroCom Experiment B

Prescribed emissions:

- 2d/3d fields for dust, sea salt, SO2, SO4, DMS, BC, POM
- Particle sizes



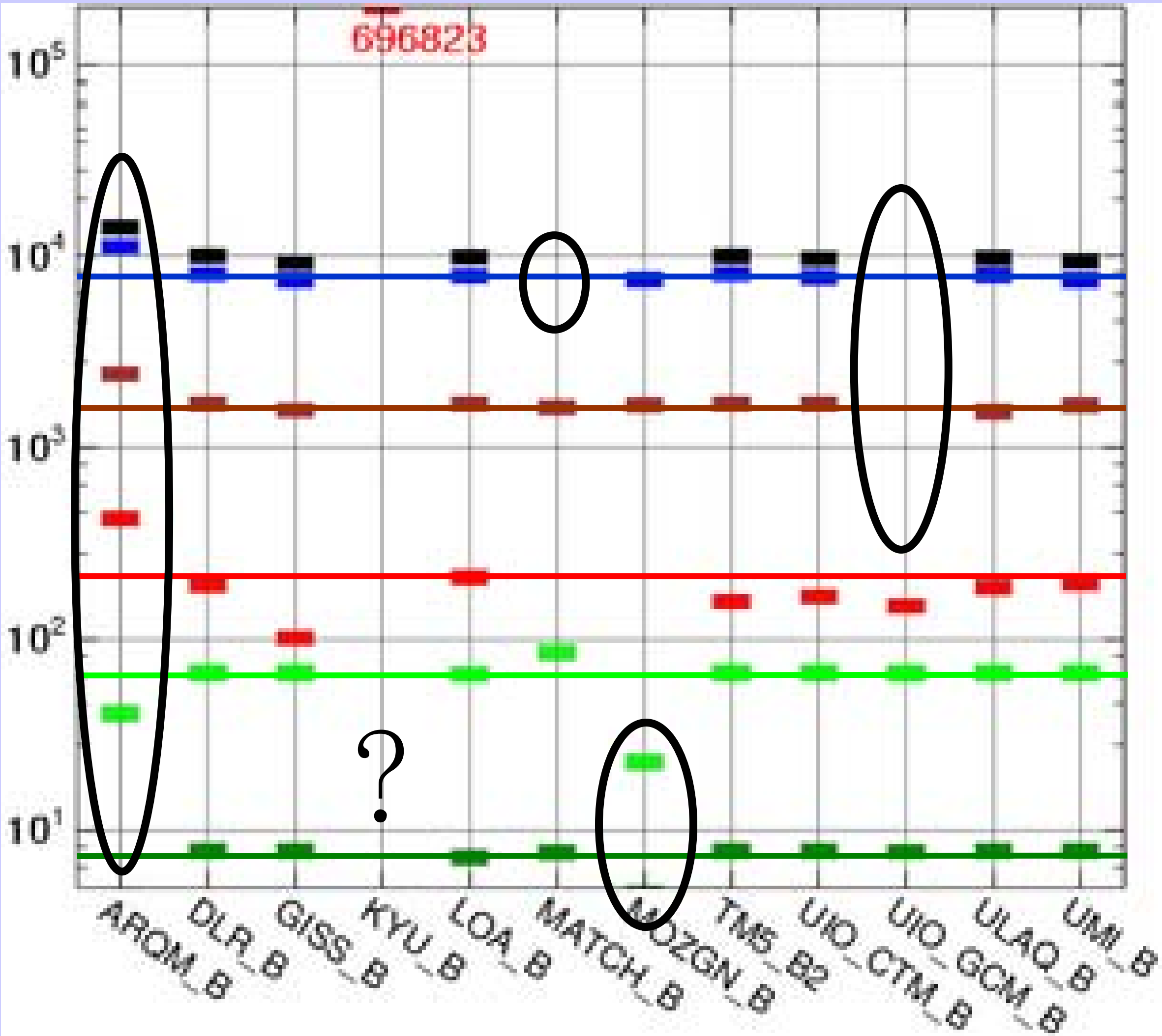
Aerocom B emissions: potential problems

- How are the fields interpolated to the model grid?
- How are the emissions filled into the vertical grid?
- How are the sizes represented in the different schemes?
- Bugs…

- Volcanic emissions height intervals

Explosive	intended:	top+500m	->	top +1500m
	given:	66% top	->	top
Continuous	intended:	66% top	->	top

Exp B: „unified" gobal aerosol emissions



AEROCOM B models

[Tg/year]

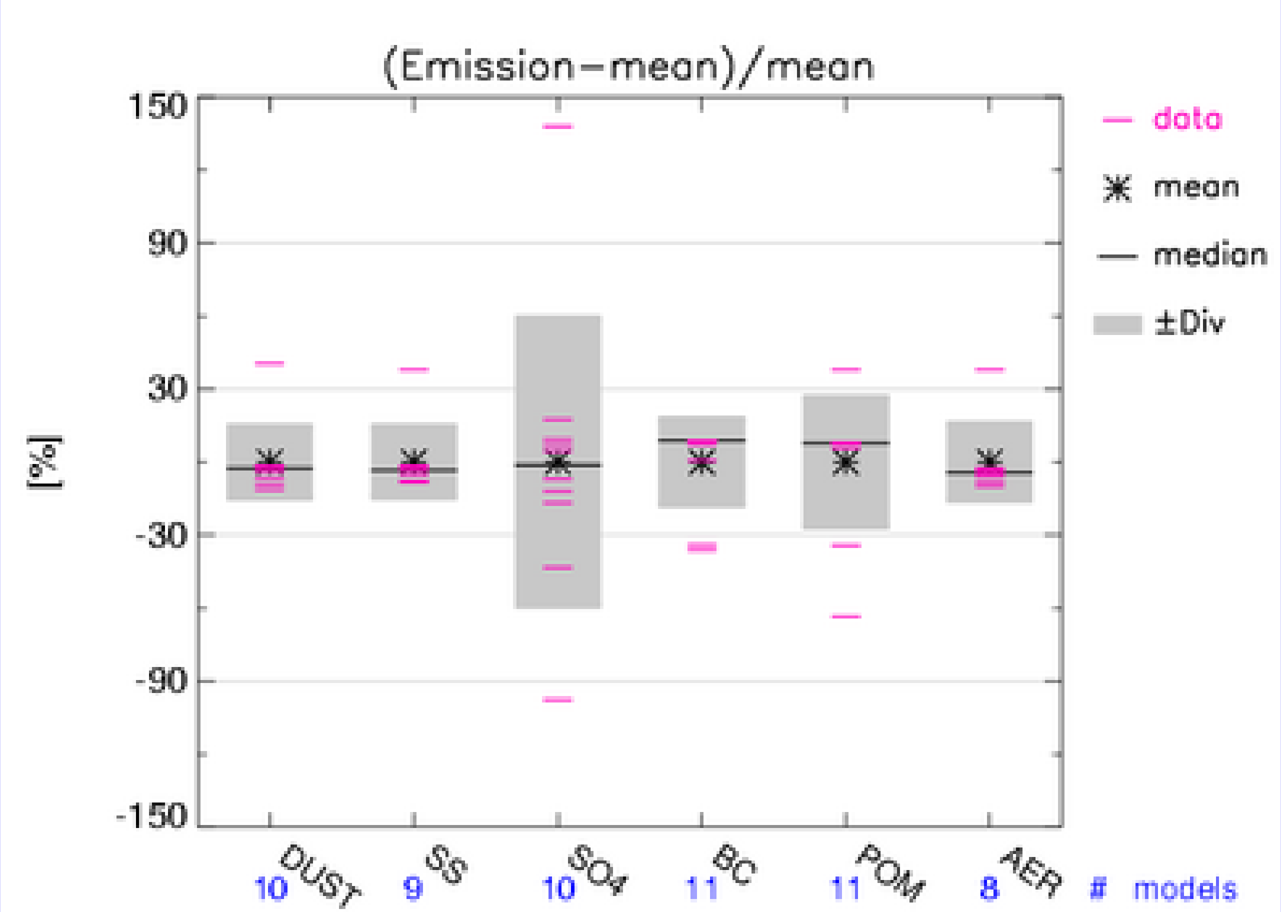
global annual averages
year 2000 if available

expB: SO2 + SO4 + DMS
models: emi+chep SO4

dust
sea salt
sulfate
black carbon
particul.organ.matter
total aerosol

SO4 [TgSO4/a]

Model diversity of unified emissions in Exp B



$$\text{data} = \frac{\text{model-all models average}}{\text{all models average}} * 100$$

diversity = Standarddeviation of data

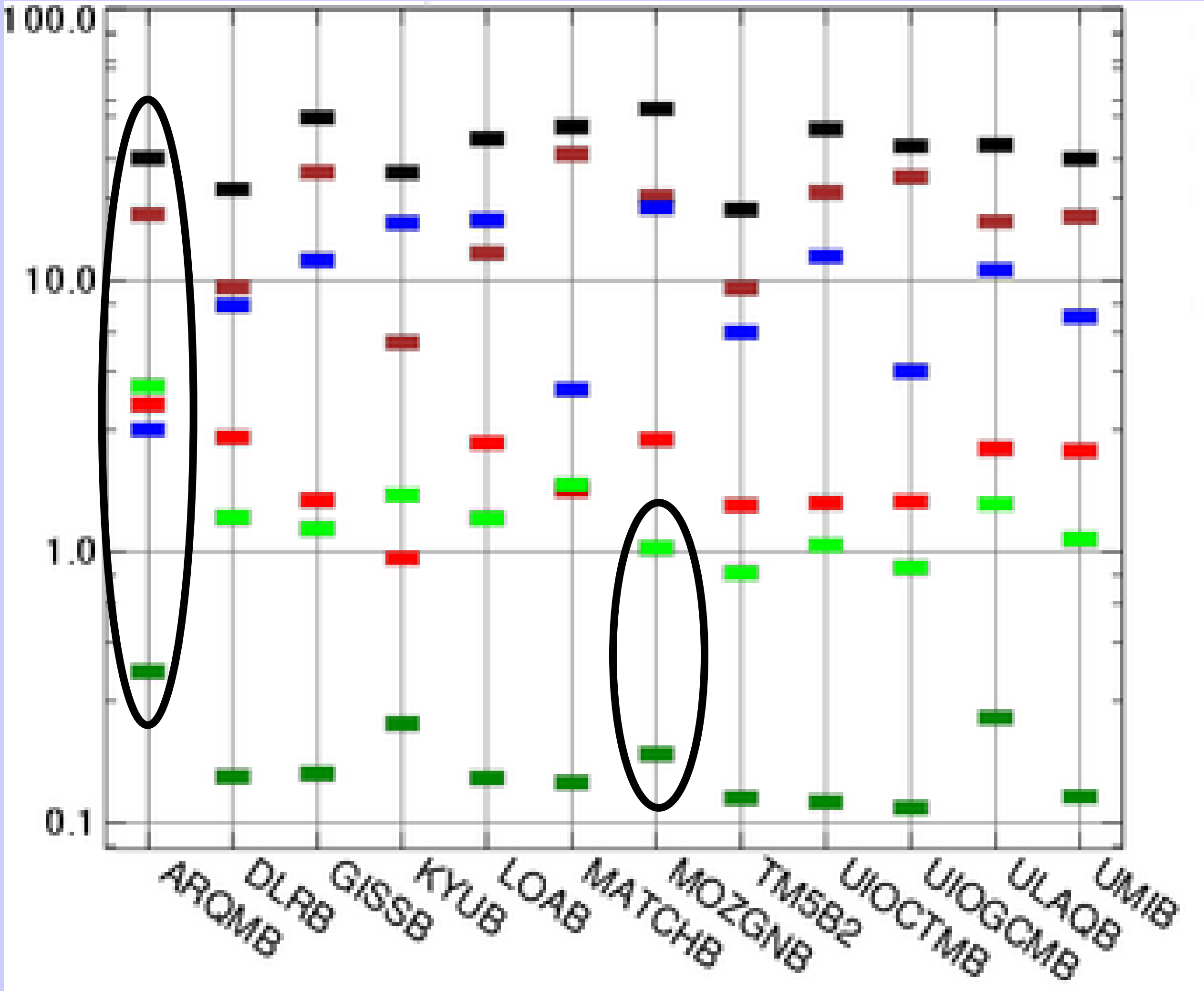
Comparison between Exp A and B

Differences in model versions:

- KYU indirect effect included
- DLR coarse mode included,
  updated water uptake (EQSAM)

- Other models: minor changes !

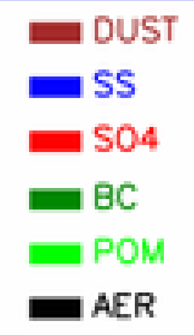
Exp B: gobal aerosol load [Tg]



global annual averages

year 2000 if available

AEROCOM B models



dust

sea salt

sulfate

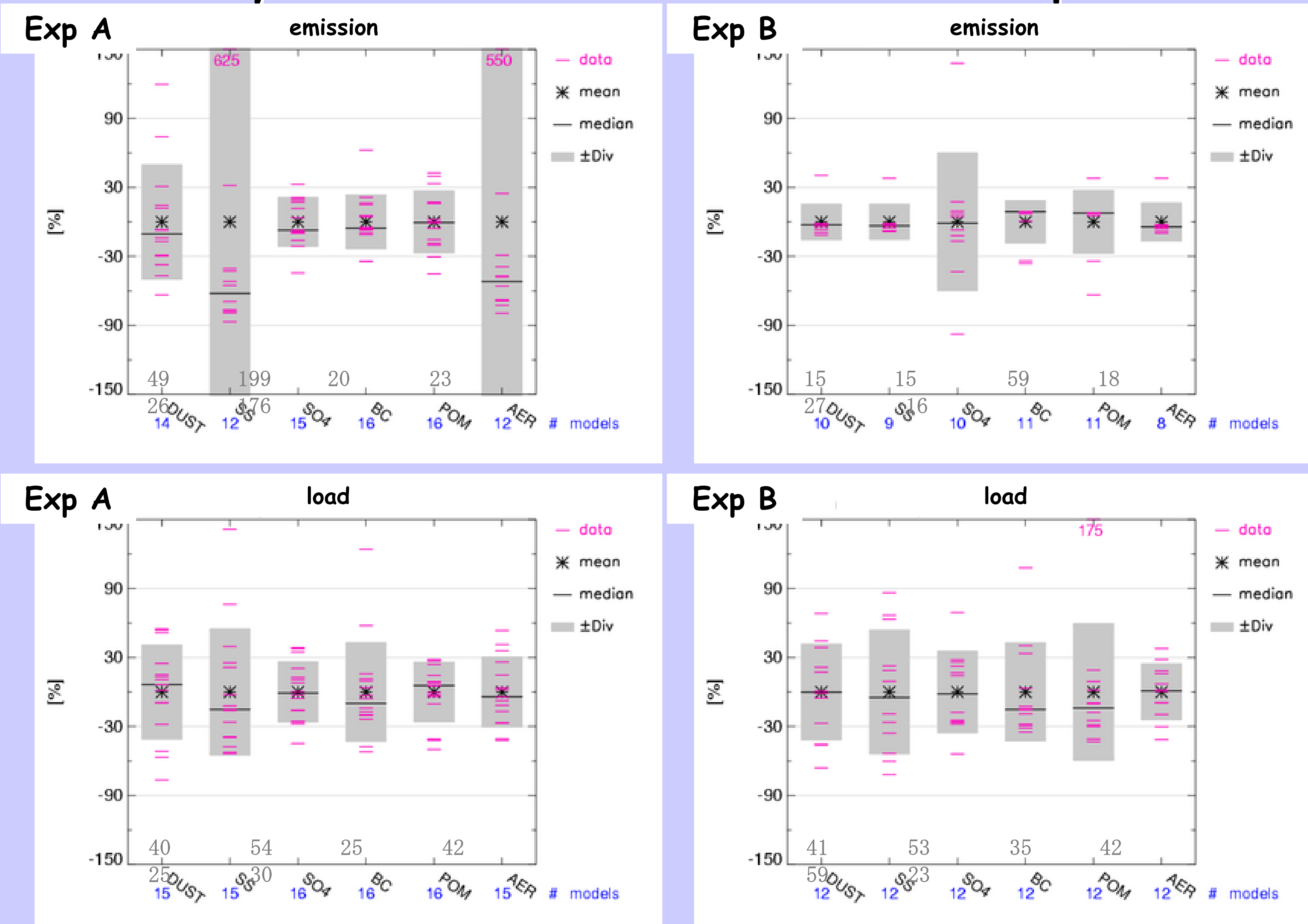
black carbon

particul.organ.matt

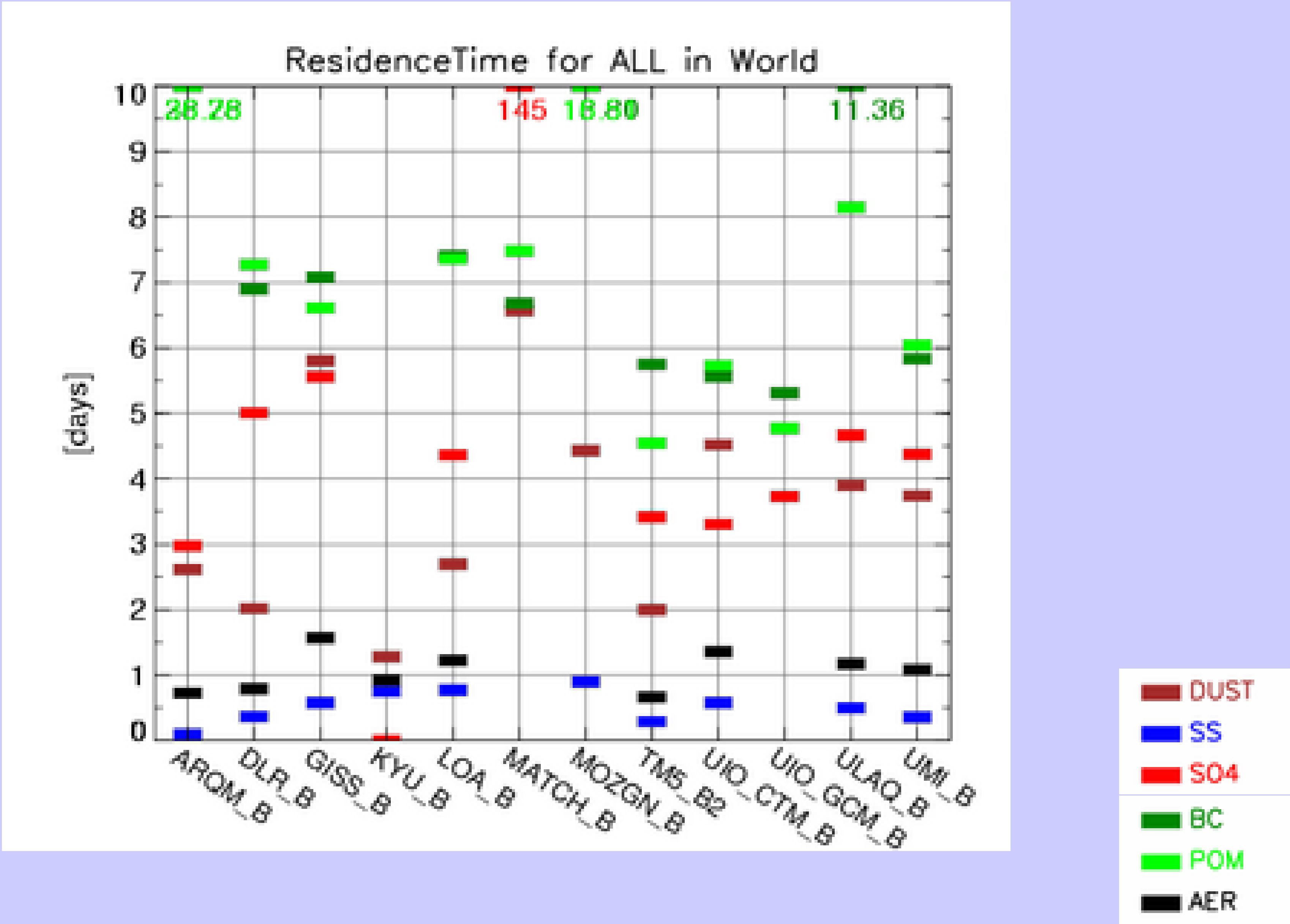
total aerosol

SO4 [TgSO4/a]

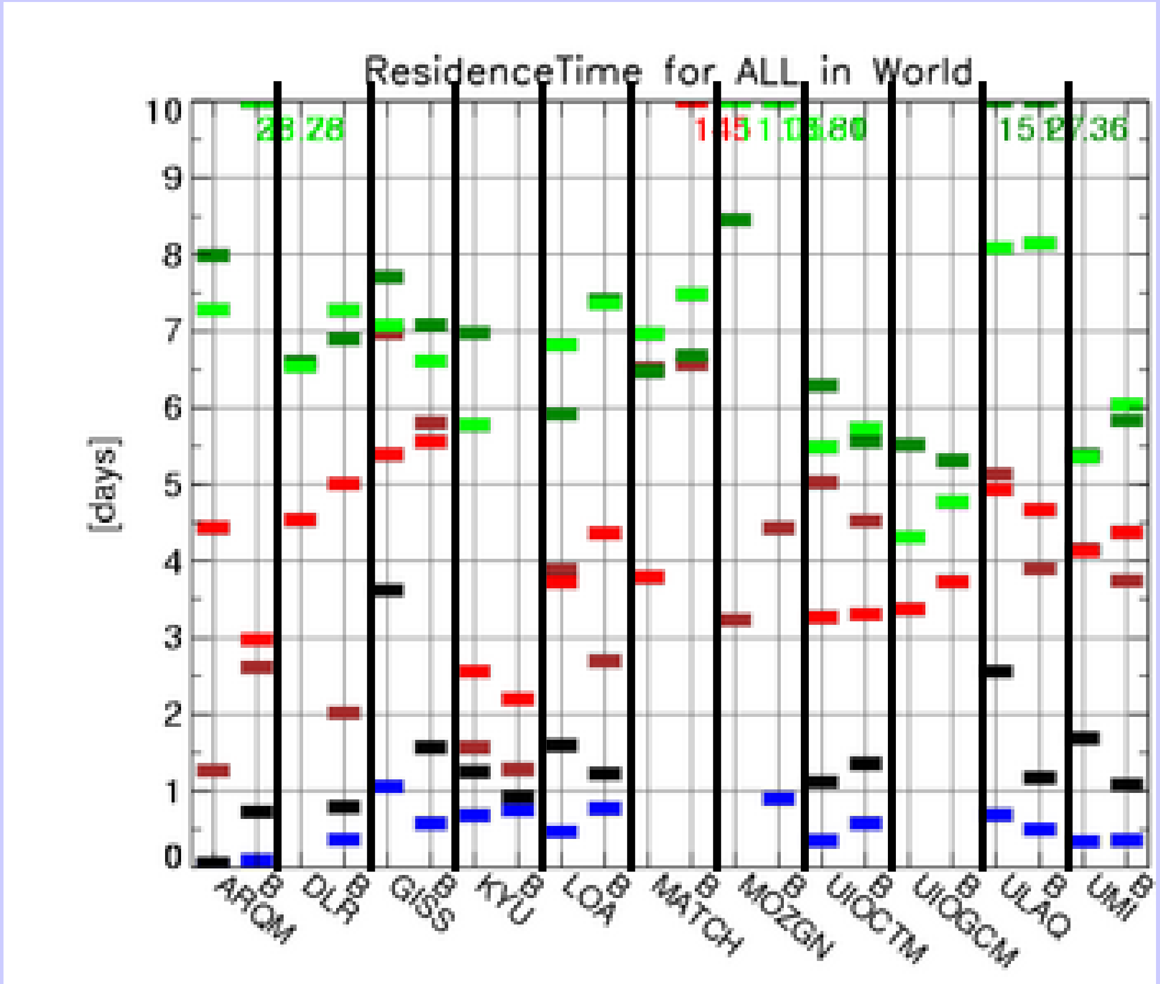
Diversity of emissions and load in Exp A and B

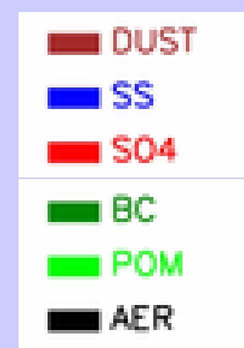


Residence times in Exp B



Residence times in Exp A and B

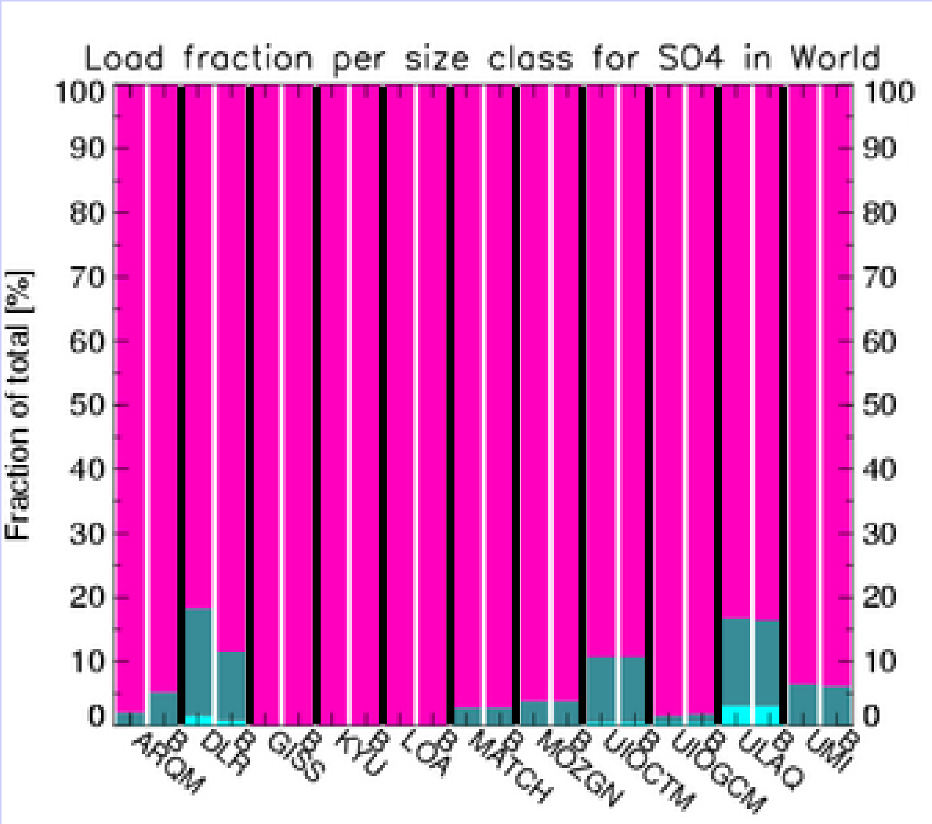




Effects of modified spatial distributions and particle size distributions.

particle sizes

Mass fraction per size class in Exp A and B



SO4

Size classes

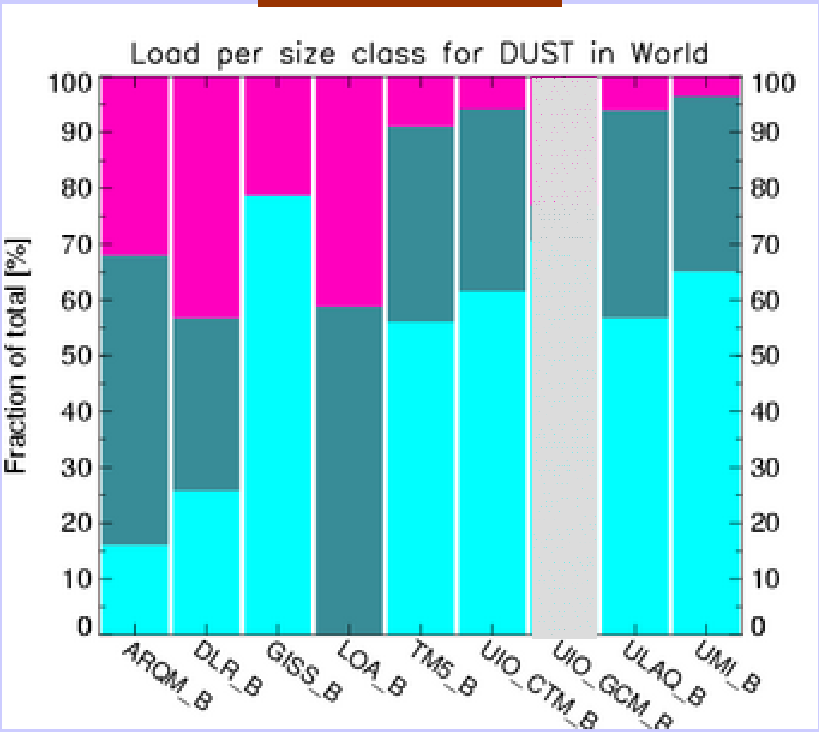
Radius intervals [mum]

Acc	<0.5
Coo	0.5 - 1.25
Sup	>1.25

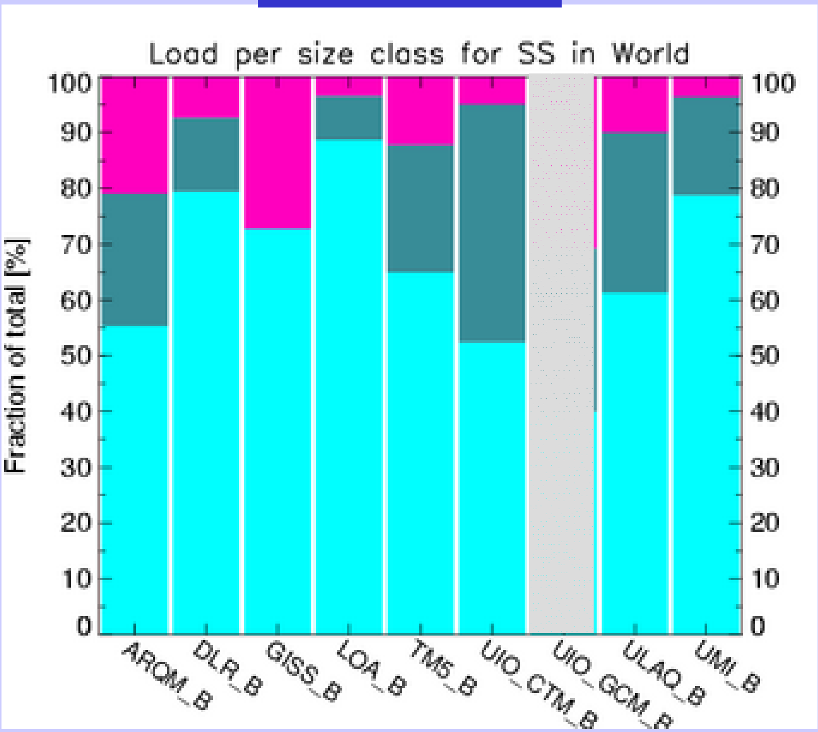
Similar sizes for fine fraction in Exp A and B

Mass fraction per size class in Exp B: DU and SS

DUST



SeaSalt



Unified size (?) of emitted particles is not transmitted to load.

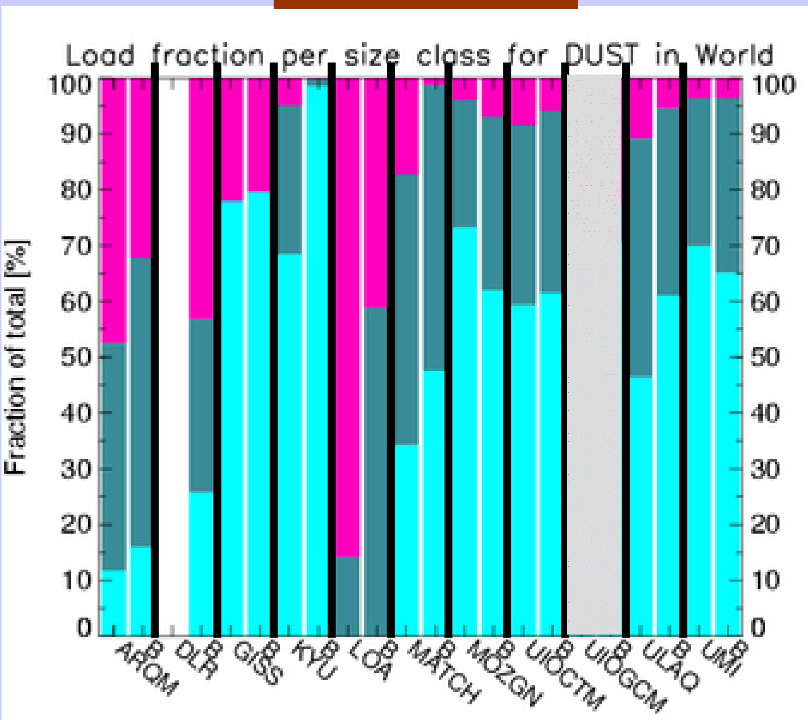
Size classes

Radius intervals [mum]

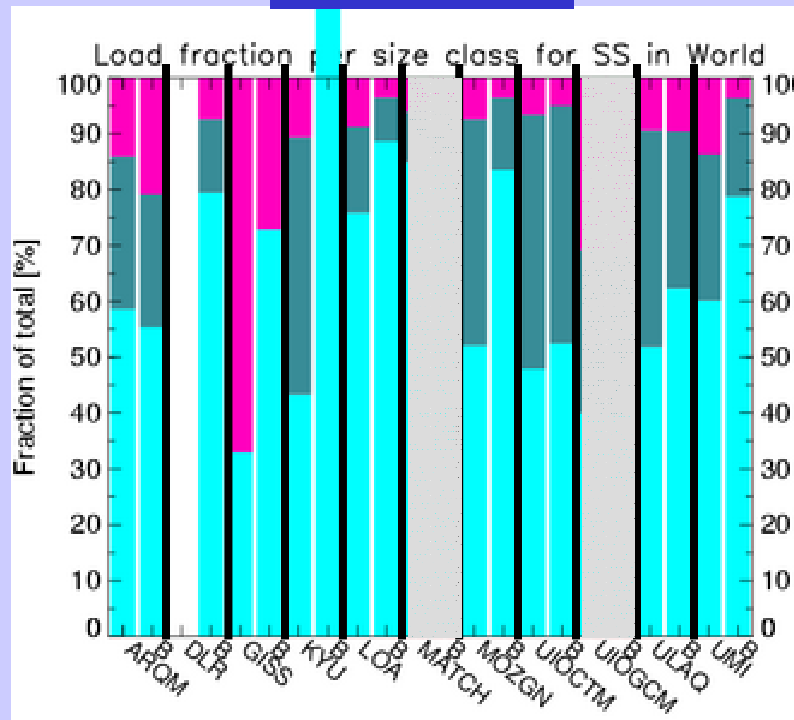
Acc	<0.5
Coo	0.5 - 1.25
Sup	>1.25

Mass fraction per size class in Exp A and B

DUST



SeaSalt



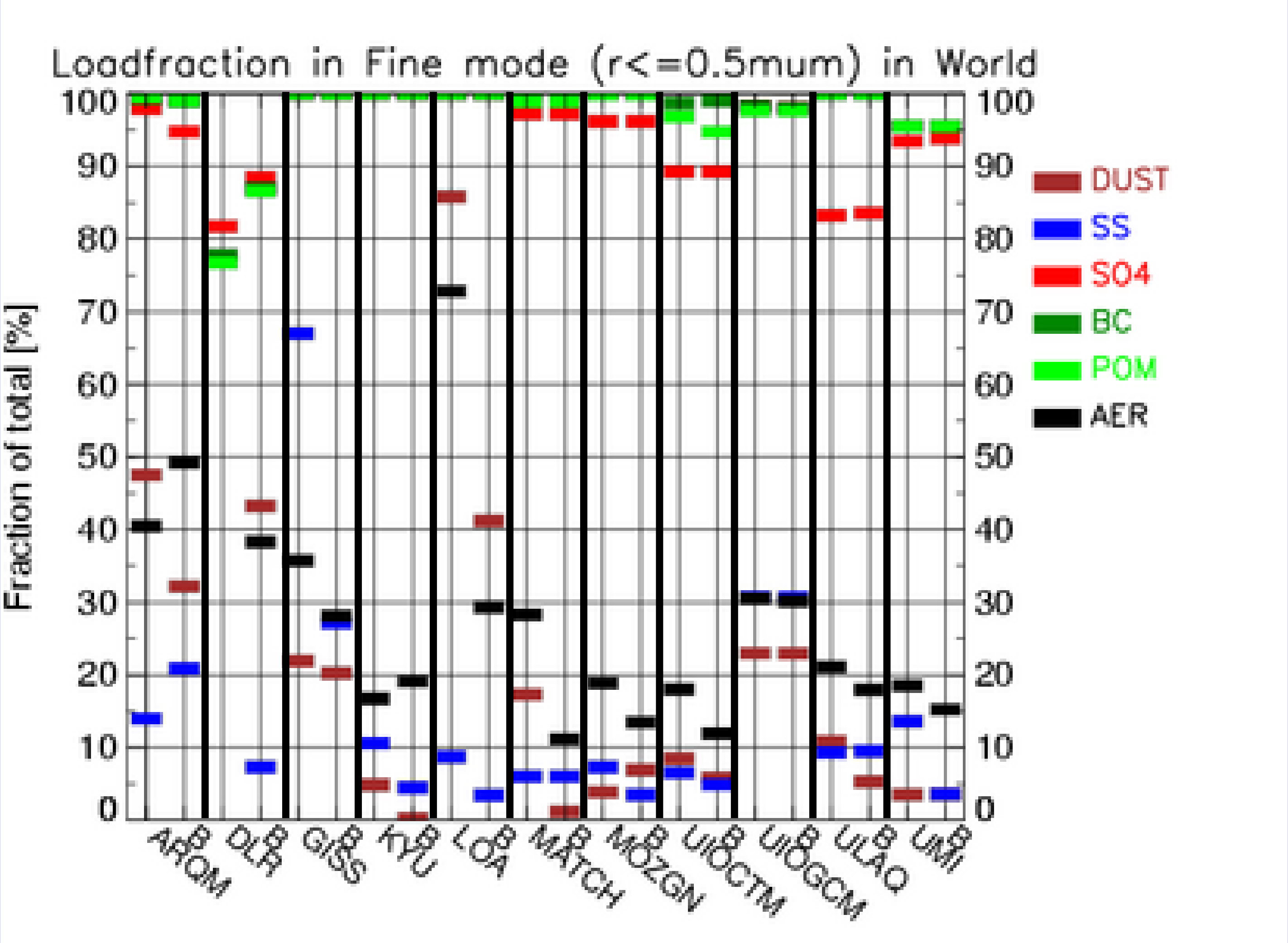
- Particle size is similar for a given model for both experiments.
- Different representation of sizes in schemes?
- Deficiency of AeroCom diagnostics?

Size classes

Radius intervals [mum]

Acc	<0.5
Coo	0.5 – 1.25
Sup	>1.25

Mass fraction in the fine mode in Exp A and B



Important implications for radiative properties!

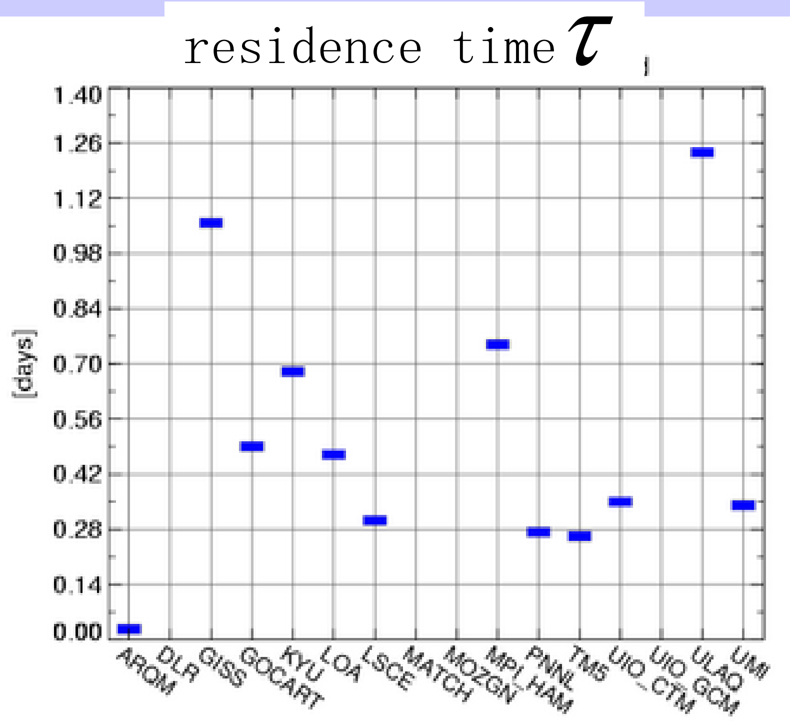
sink process analysis

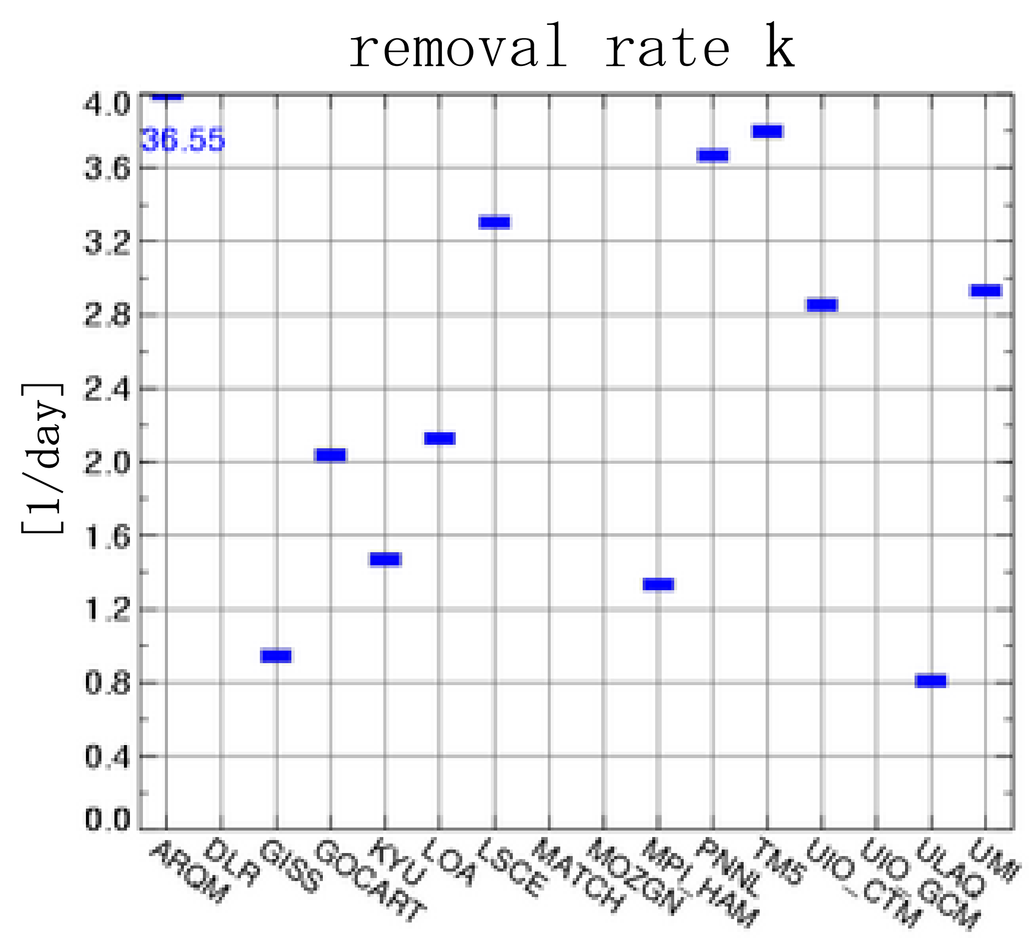
Sink process analysis

Definition of a (global mean) removal rate coefficient: $k = \frac{1}{\tau}$

$$-\frac{dm}{dt} = \tau^{-1} m = k\ m$$

SeaSalt

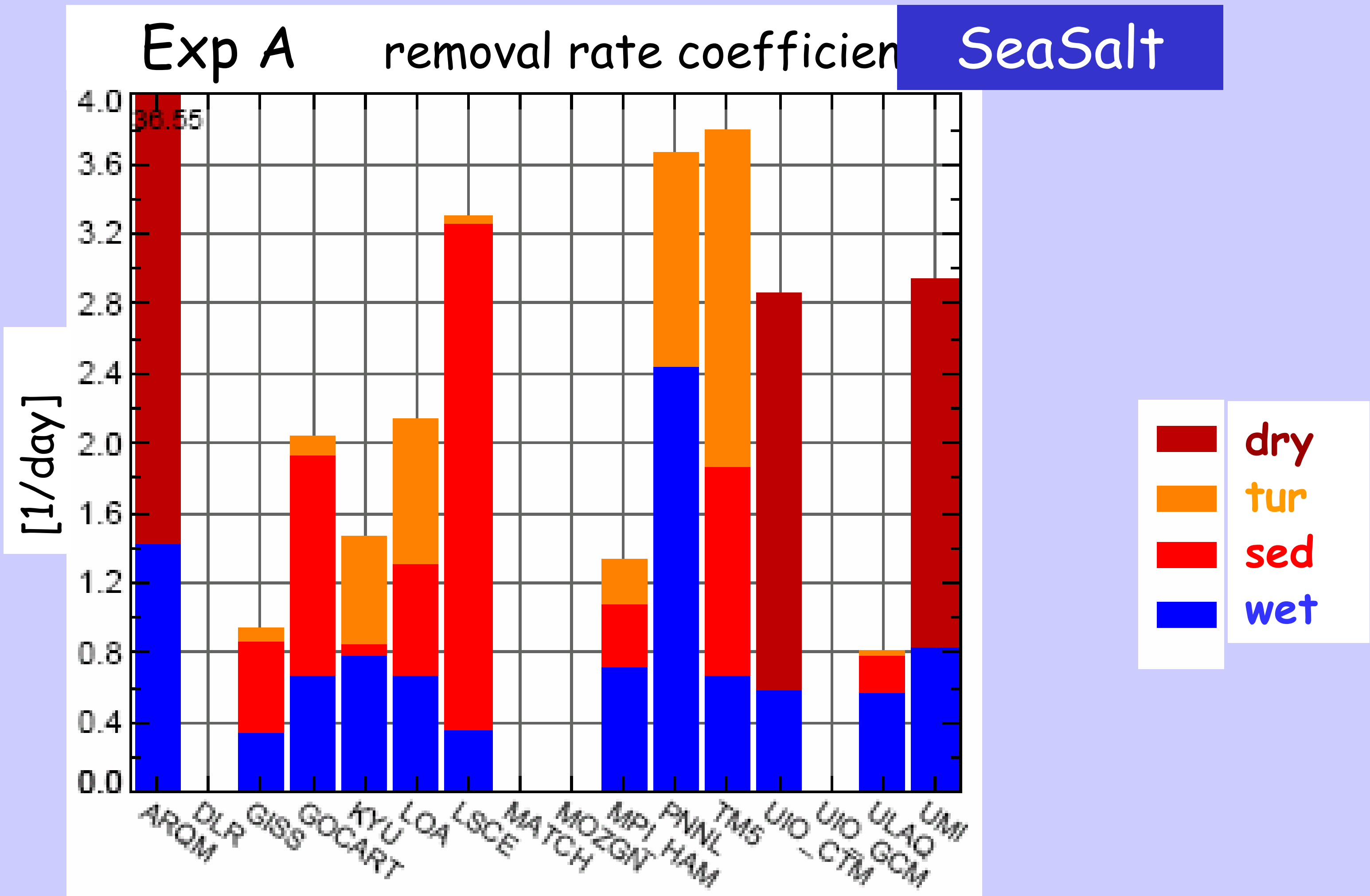




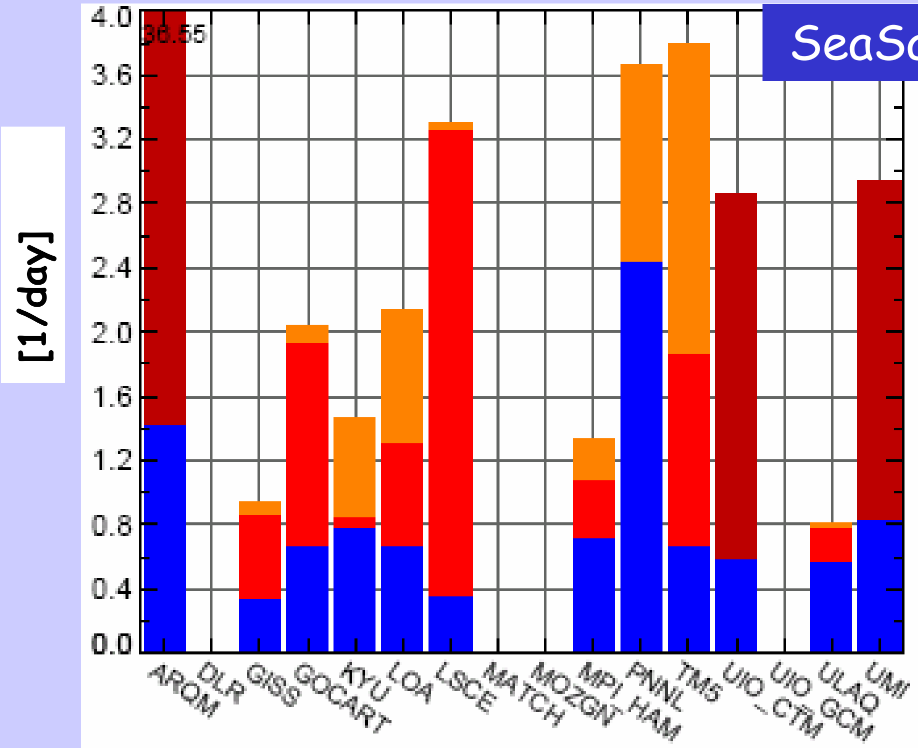
Sink process analysis

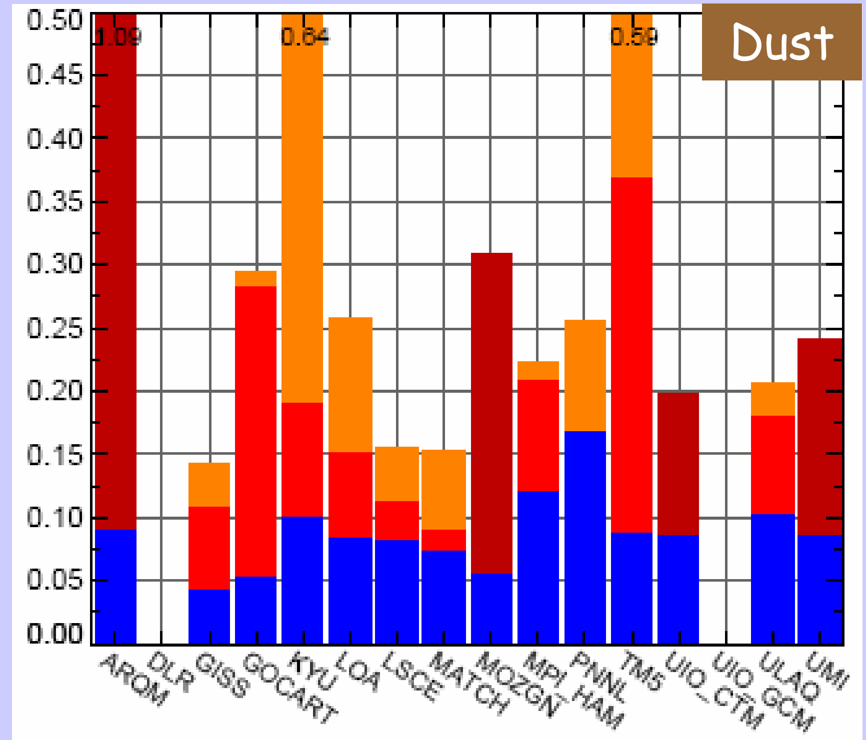
The removal rate coefficients of the single processes are:

- additive $k = k_{wet} + k_{tur} + k_{sed}$
- independent from the source strength



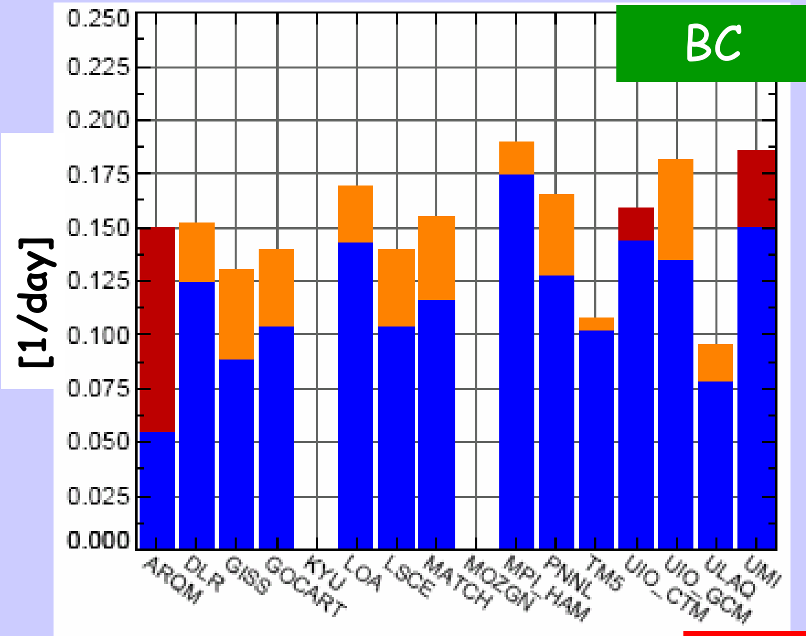
Removal rate coefficients of natural species (Exp A)

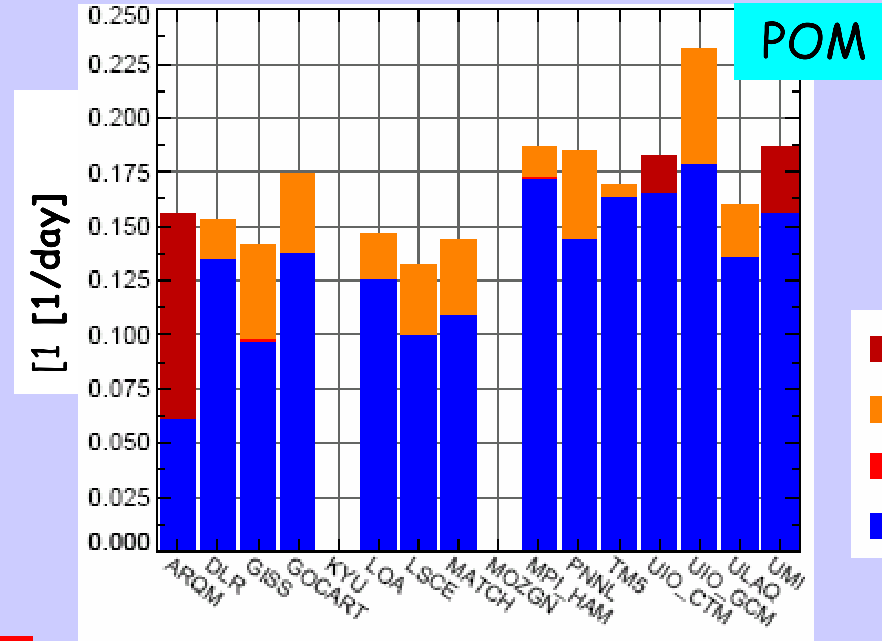


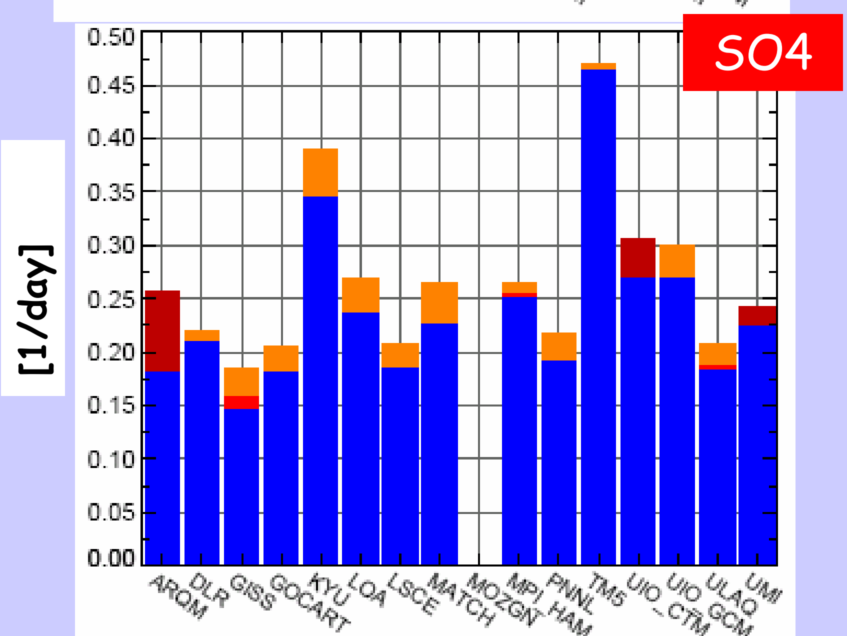


- two thirds are removed by dry deposition
- high diversities of the sink rates
- high diversity of
  - the contribution of wet deposition
  - the dominant dry deposition pathways

Removal rate coefficients of anthropogenic species







- little diversity for dominant sink
- wet dep > 80%
- rates decrease from SO4 / POM / BC

Sink processes analysis

The rates differ between the species:

- **wet removal rates**
  increase with the solubility
  from DU, BC, POM to SO4 and SS.

- **dry removal rates**
  increase with the particle sizes.

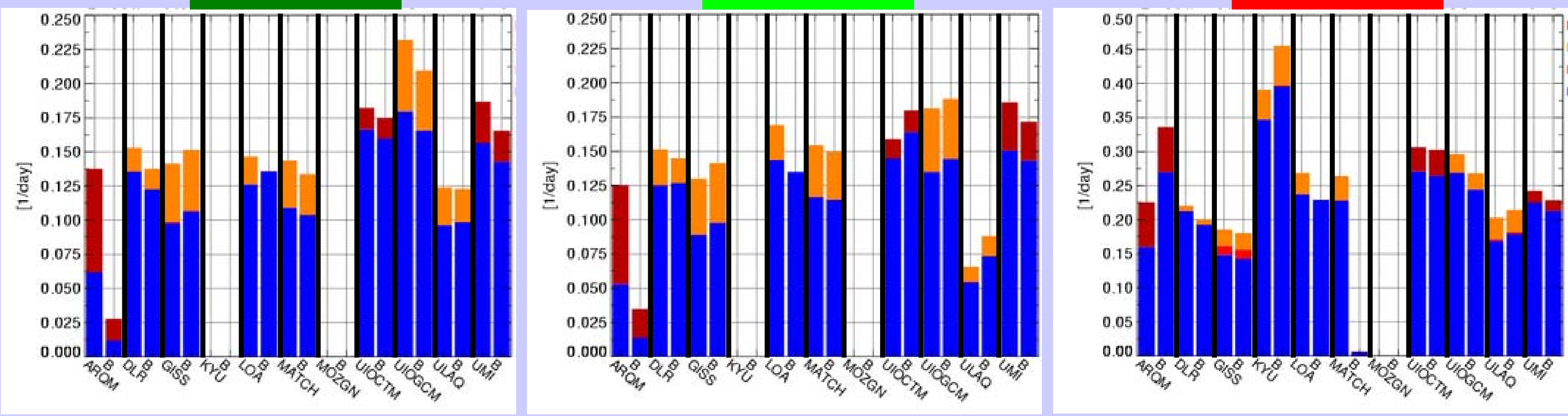
- **main removal processes**
  BC, POM to SO4: > 80% wet dep.
  DU andSS: ~66% dry dep.

Why do the removal rates for a given species differ between the models ?

Removal rate coefficients
Exp A and B: fine fraction

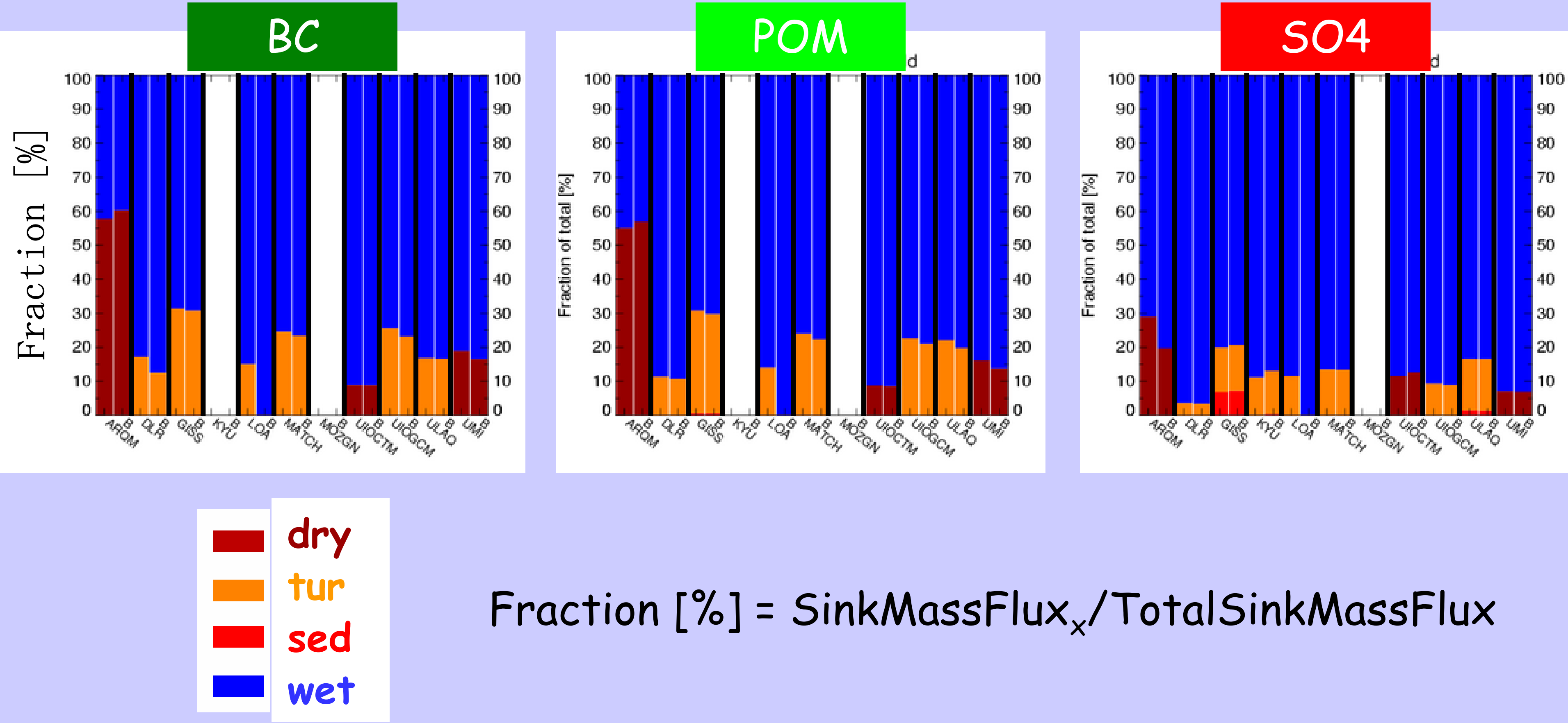
dry
tur
sed
wet

BC | POM | SO4



Results of the two exp's are similar for of a given model.

Removal pathways in Exp A and B: fine fraction

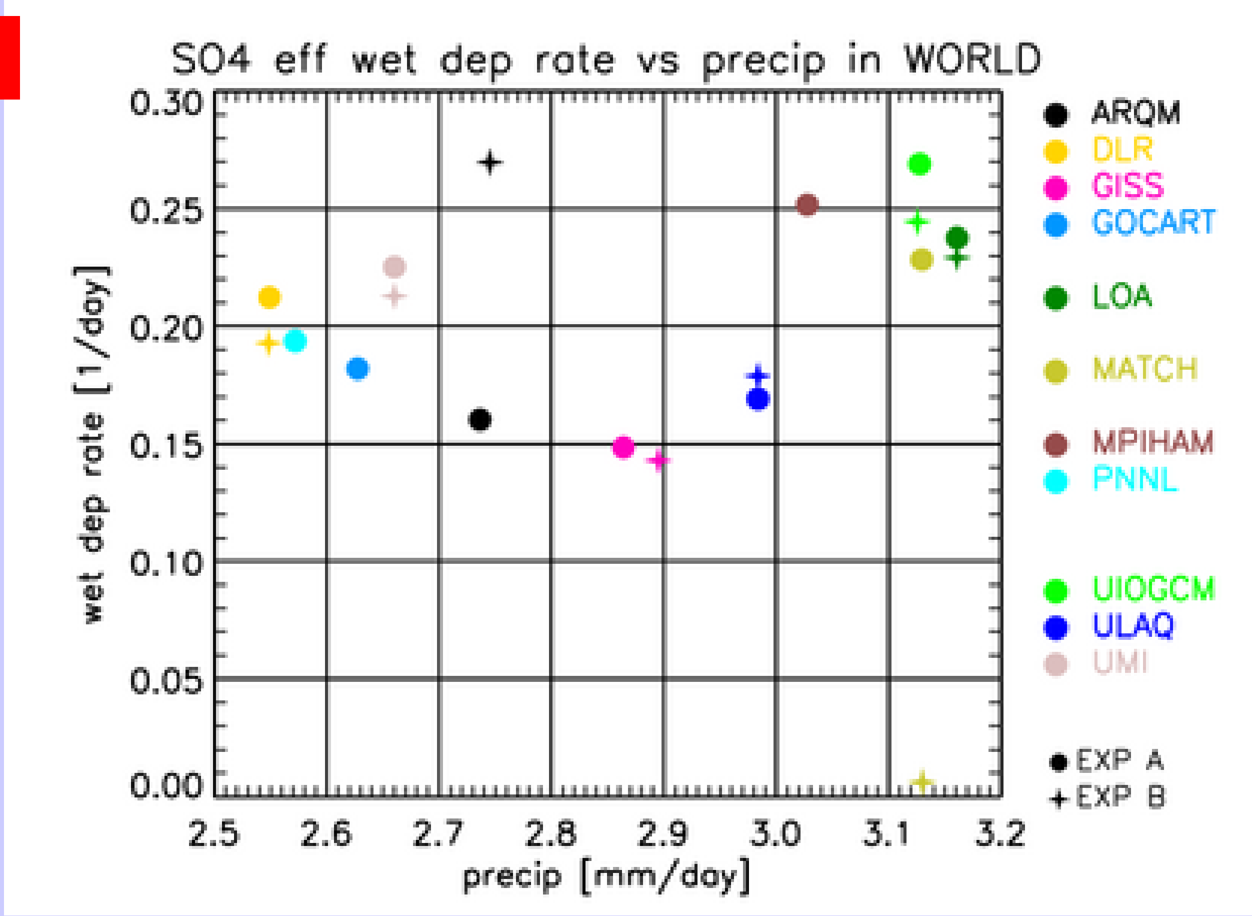


Fraction [%] = $SinkMassFlux_x / TotalSinkMassFlux$

- Relative importance of removal pathways is model-specific.
- Minor effects of spatial distributions.

Wet dep rate coeff. vs. Precipitation rate

SO4



Wet dep rate is independent from global annual precip rate.

Removal of dust and sea salt

dry
tur
sed
wet

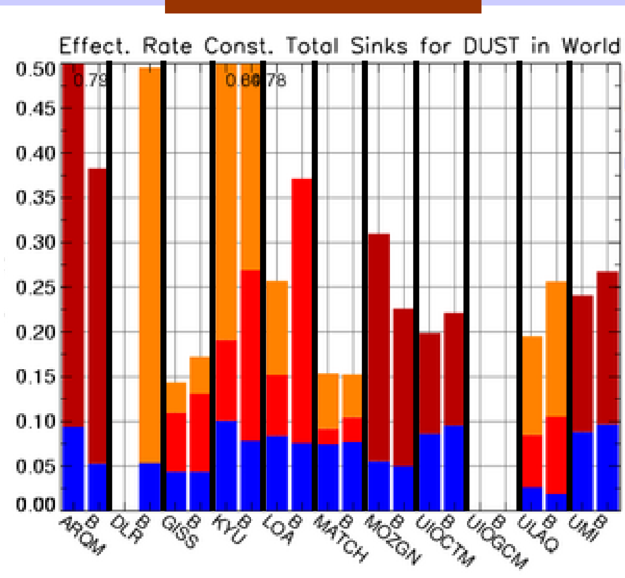
DUST

SeaSalt

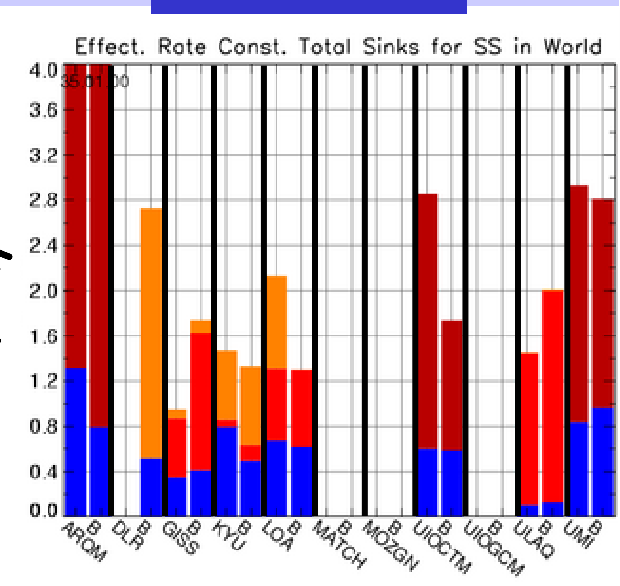
removal rate coeff.

k [1/day]

1/day



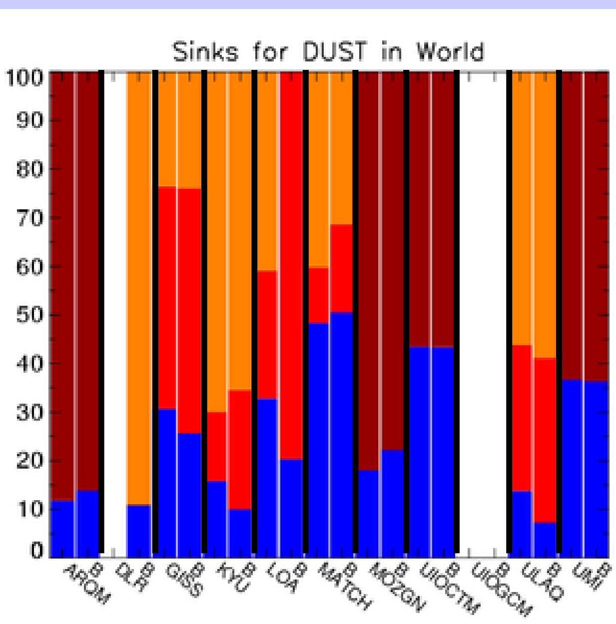
1/day



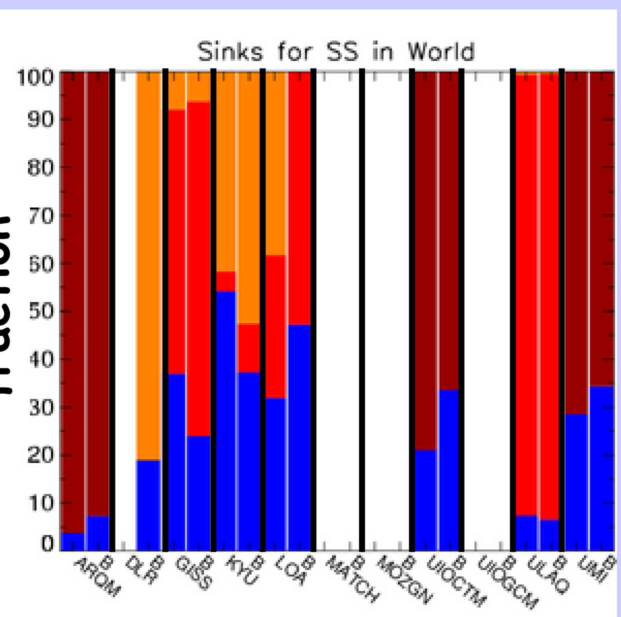
removal path way

mass fraction [%]

fraction

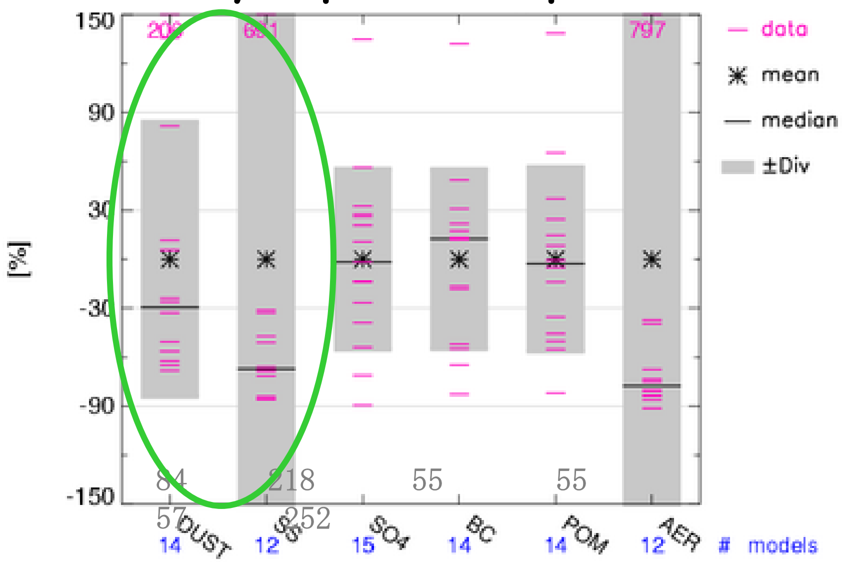


fraction

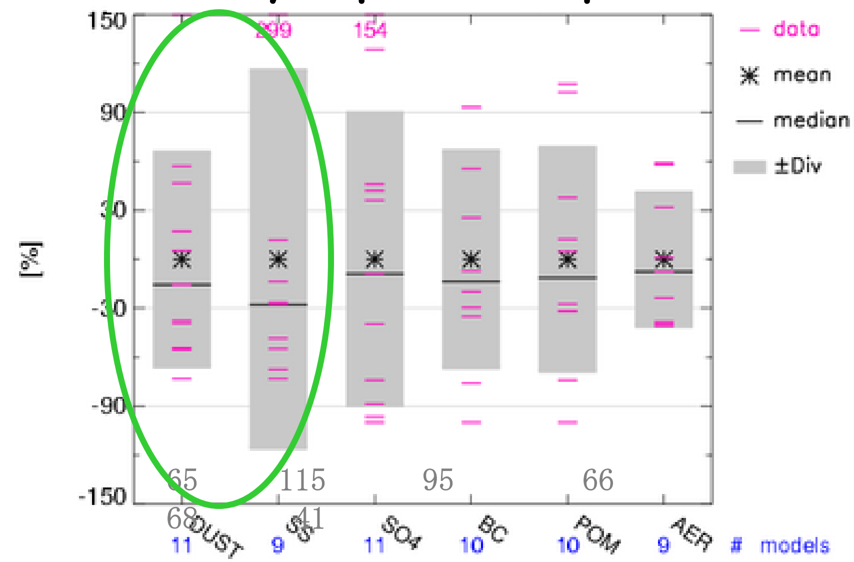


Model diversity of removal rate coefficients

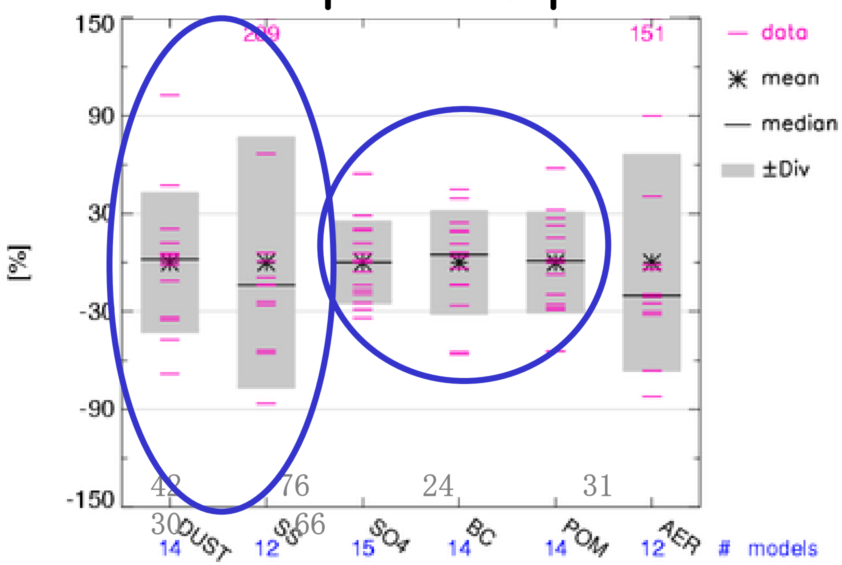
dry deposition Exp A



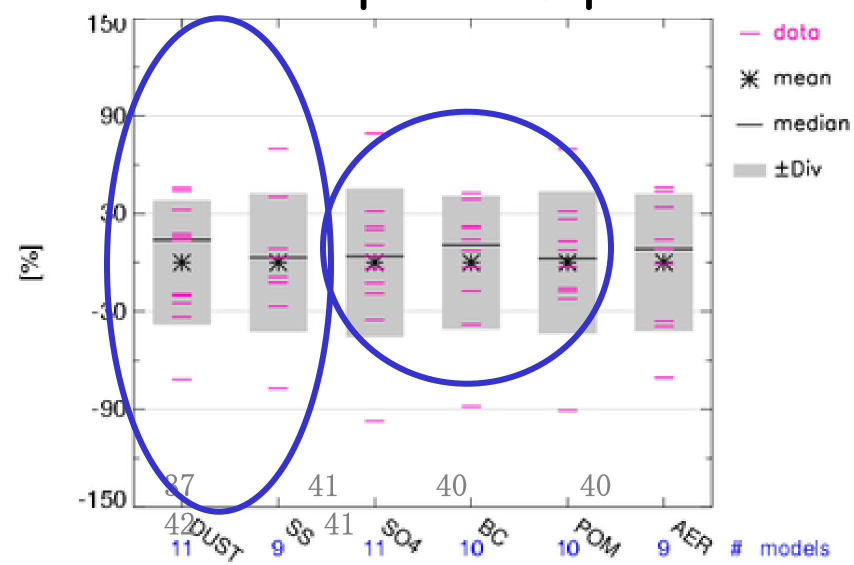
dry deposition Exp B



wet deposition Exp A



wet deposition Exp B



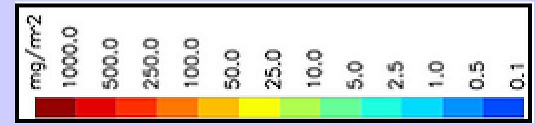
Sink processes analysis

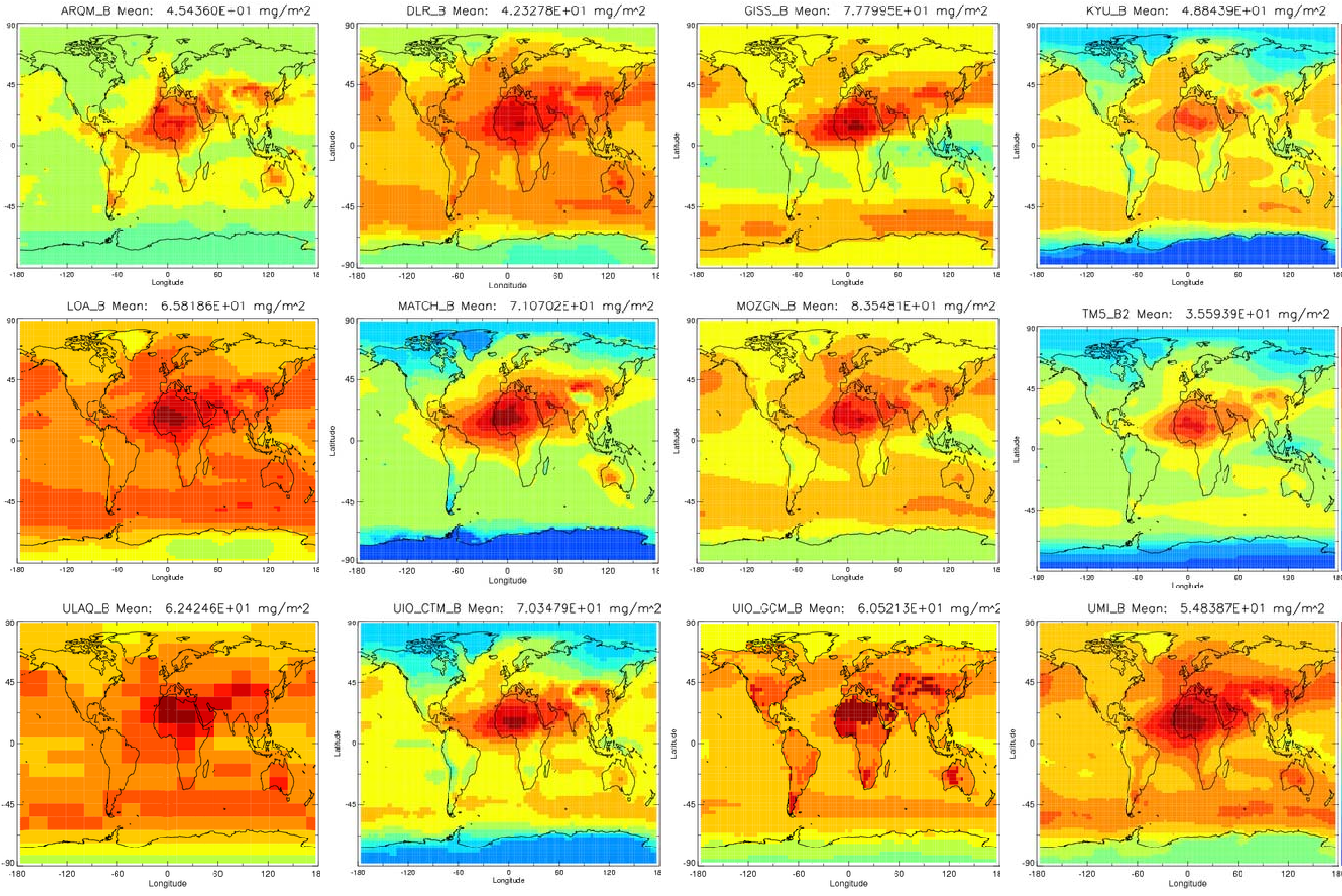
Why do the removal rates for a given species differ between models ?

- Sink processes are model specific
    - parameterizations (dep pathways)
    - dispersal
    - precipitation
    - etc…
- Spatial distribution of emissions and particle sizes seem to play minor roles.
- Model diversity of wet and dry dep in Exp A -> Exp B:
    - SS and DU: decreased: outlier removed
    - BC, POM and SO4: increased (?)

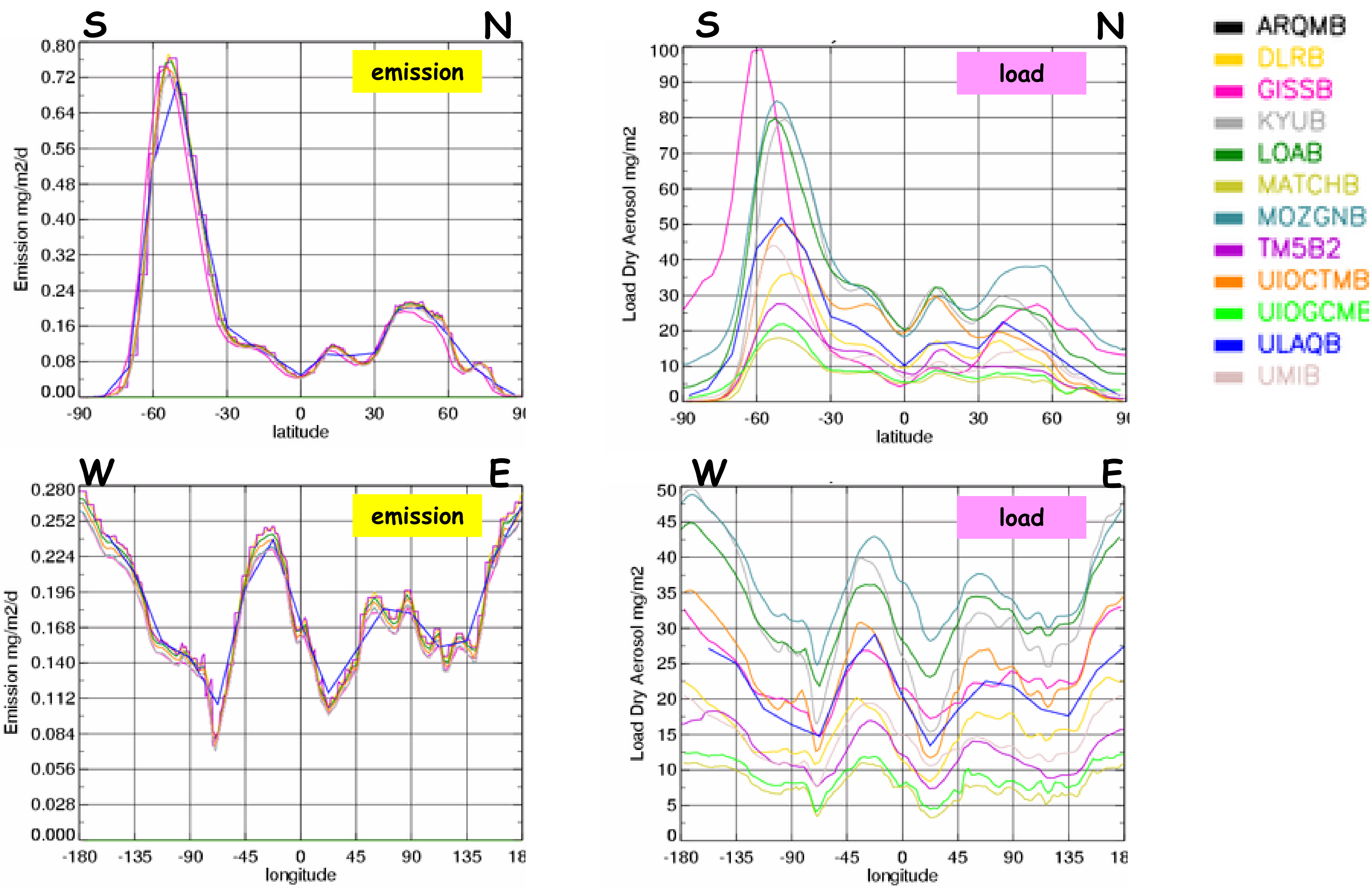
simulated spatial aerosol distributions

Aerosol load in Exp B [mg/m²]



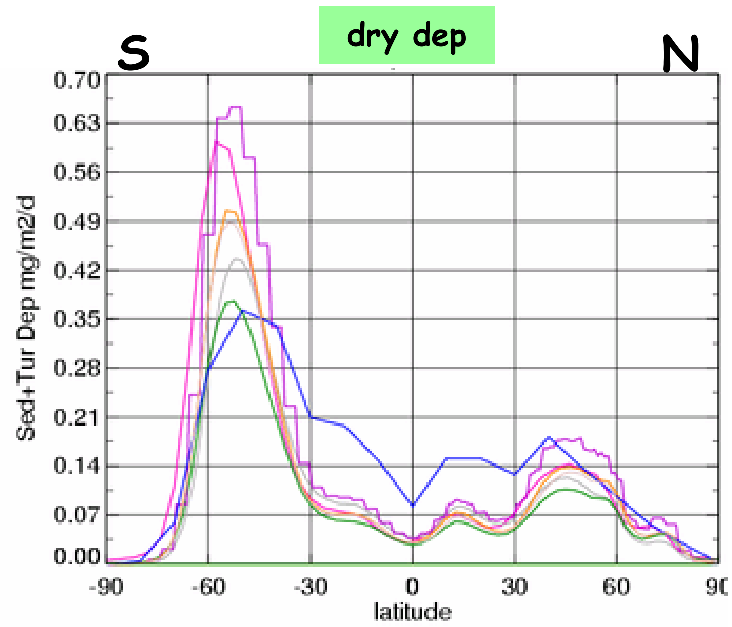


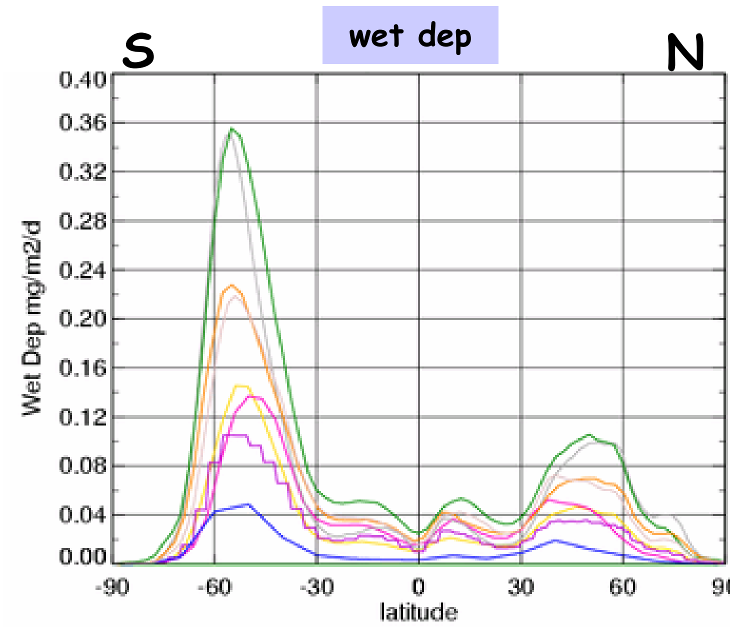
Exp B: Spatial distribution SeaSalt

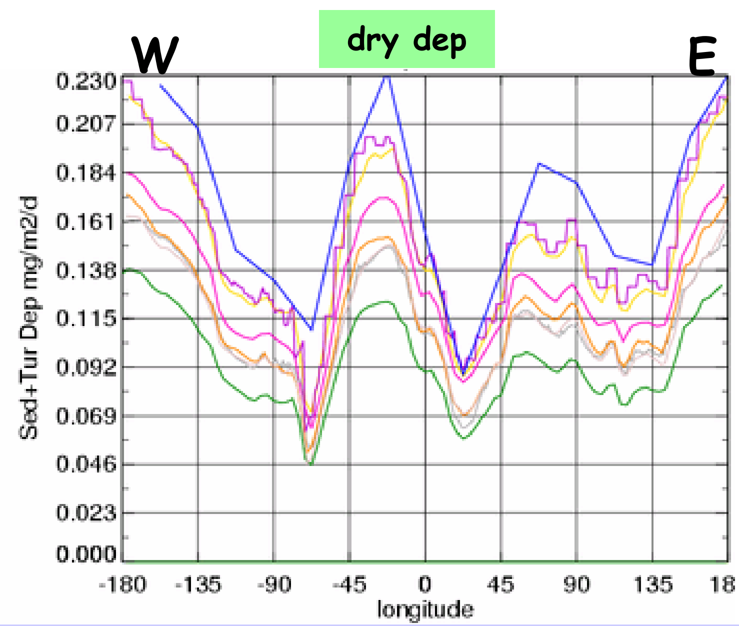


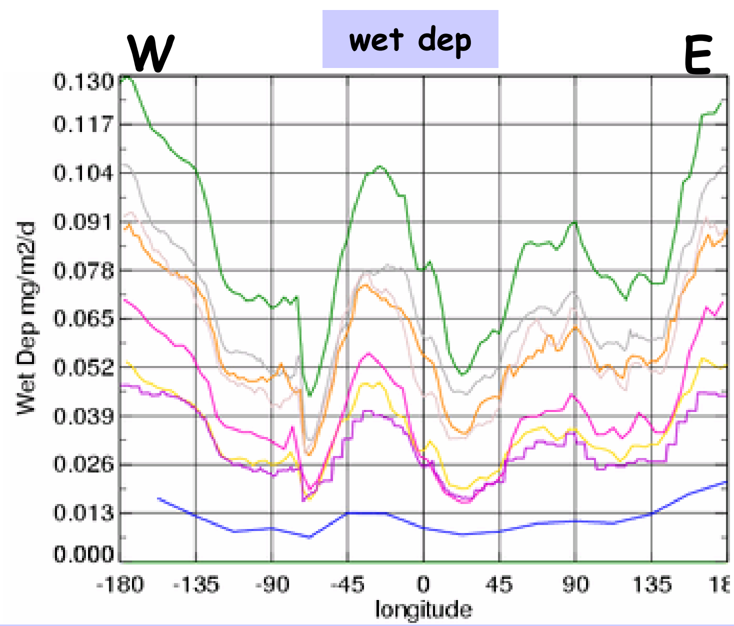
Global mean loads differ, but high agreement on spatial distribution !

Exp B: Spatial distribution SeaSalt



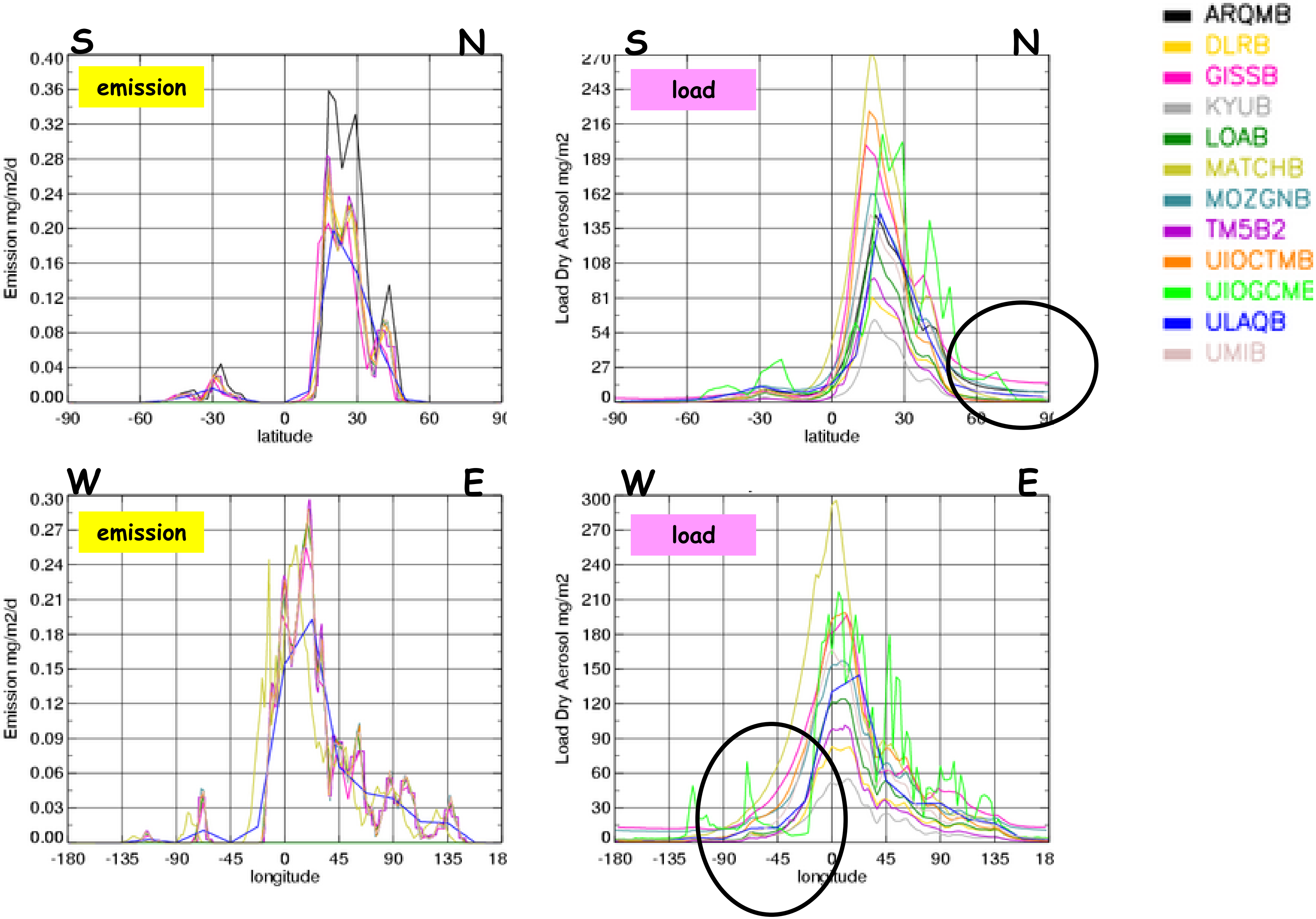




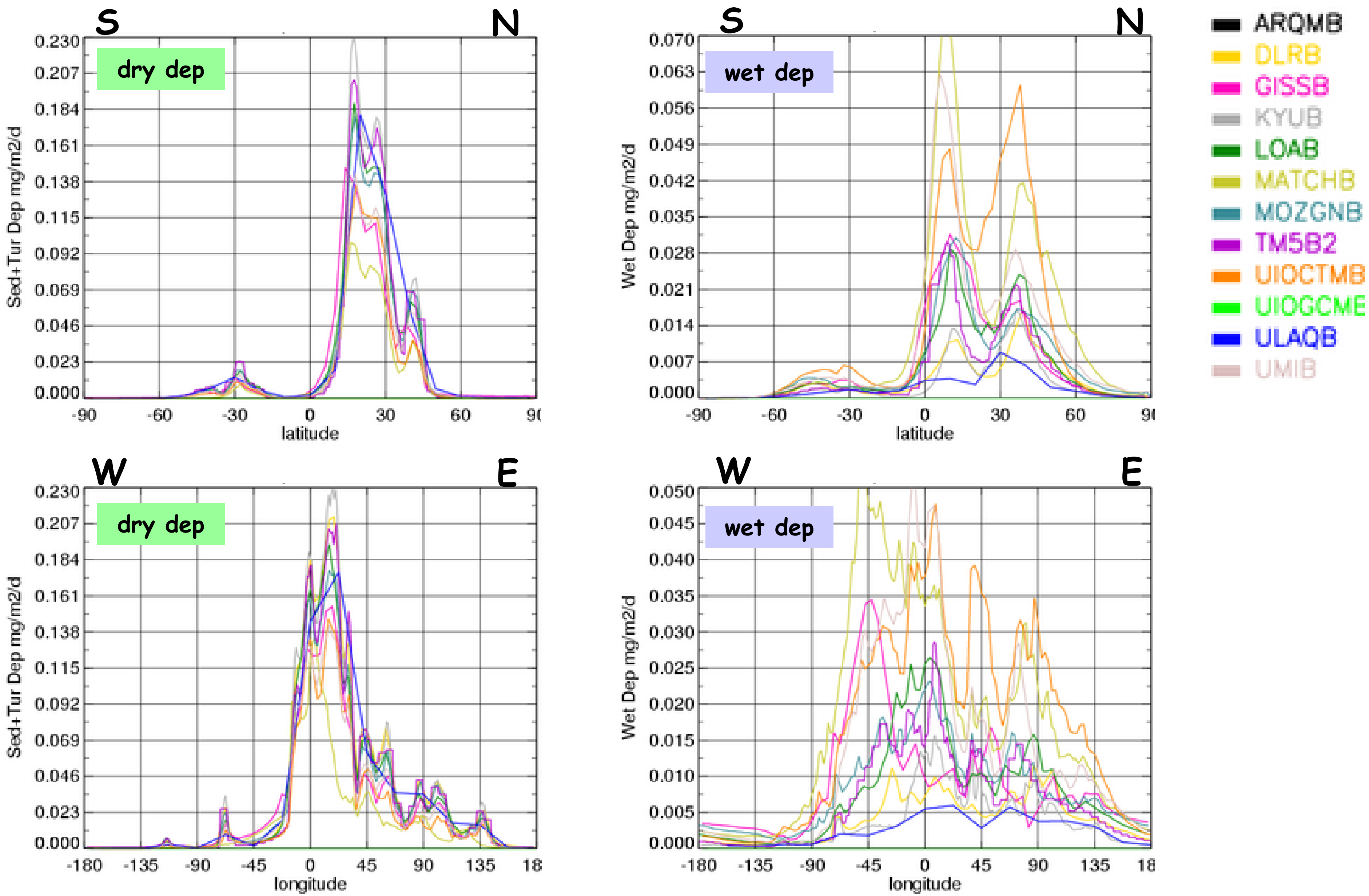


Global mean sink rates differ, but spatial distribution coincide!

Exp B: Spatial distribution DUST

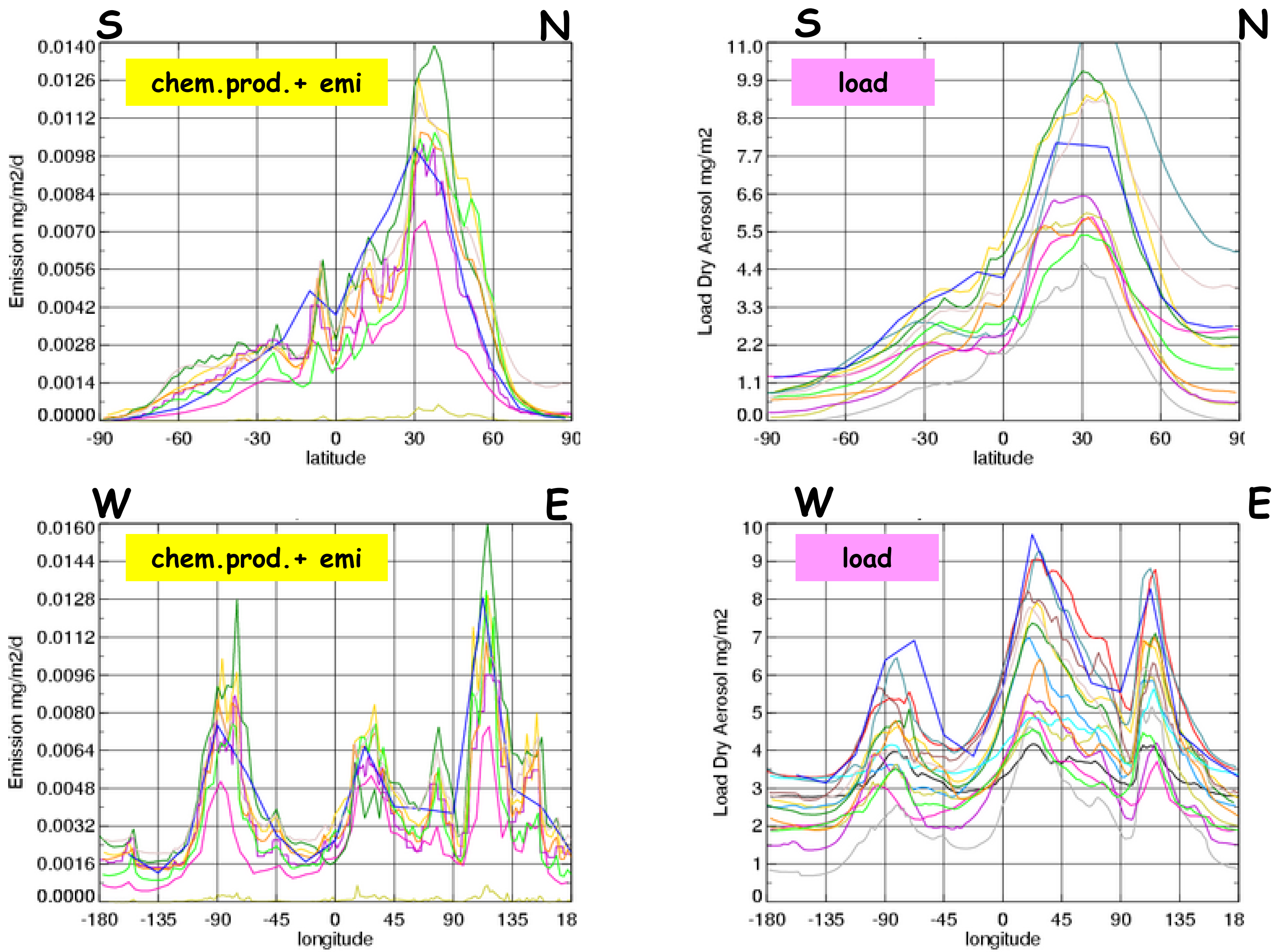


Exp B: Spatial distribution DUST



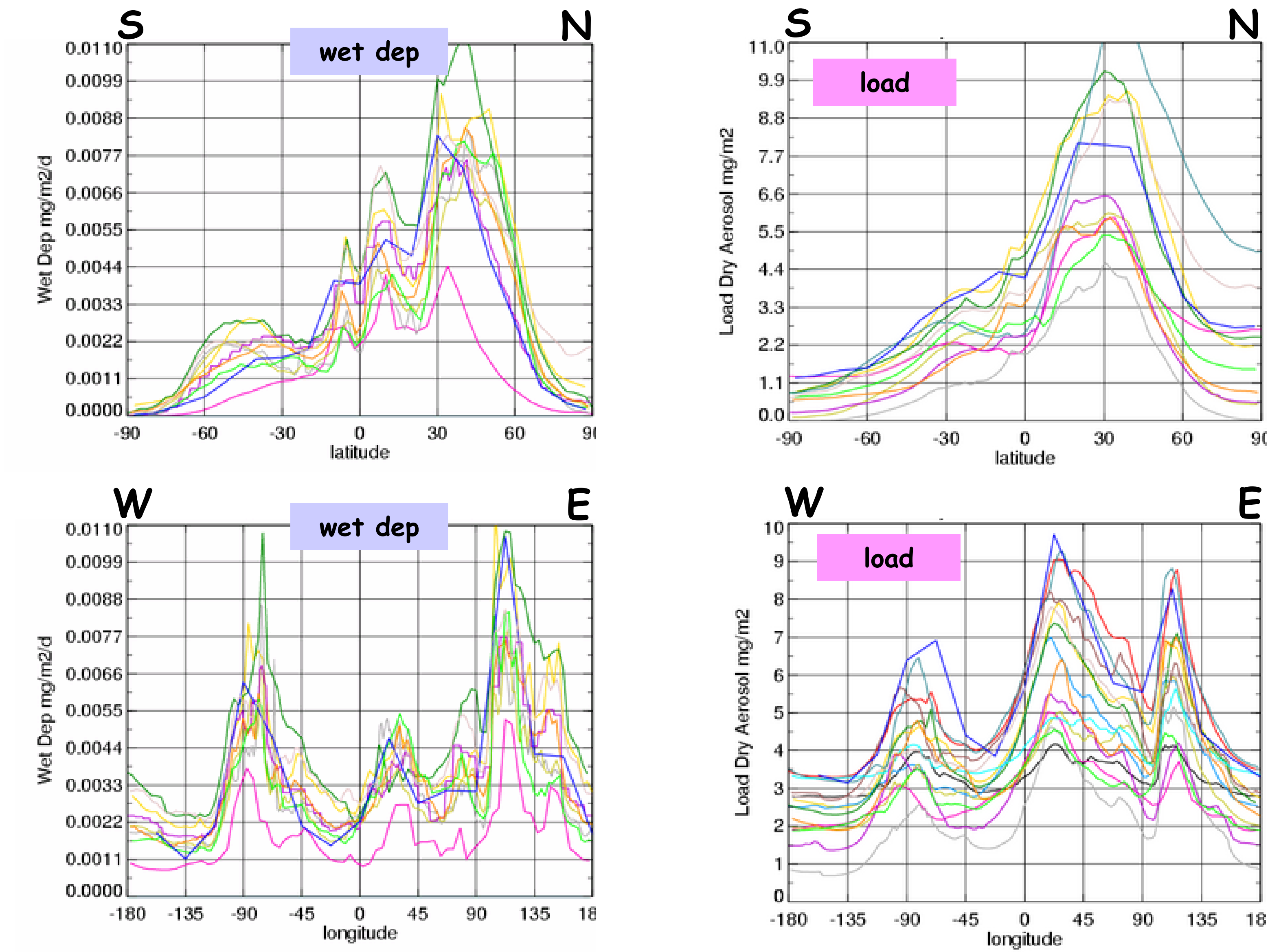
Model diversity of spatial distributions of load is due to wet dep !

Exp B: Spatial distribution SO4



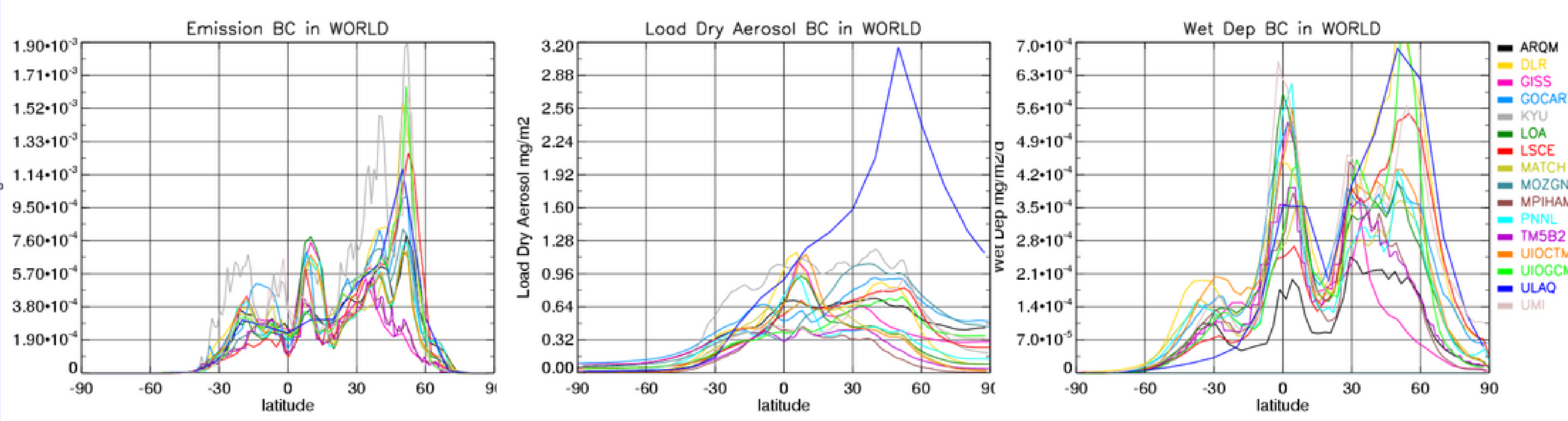
Lower agreement on emissions and load: spatial distr. + total

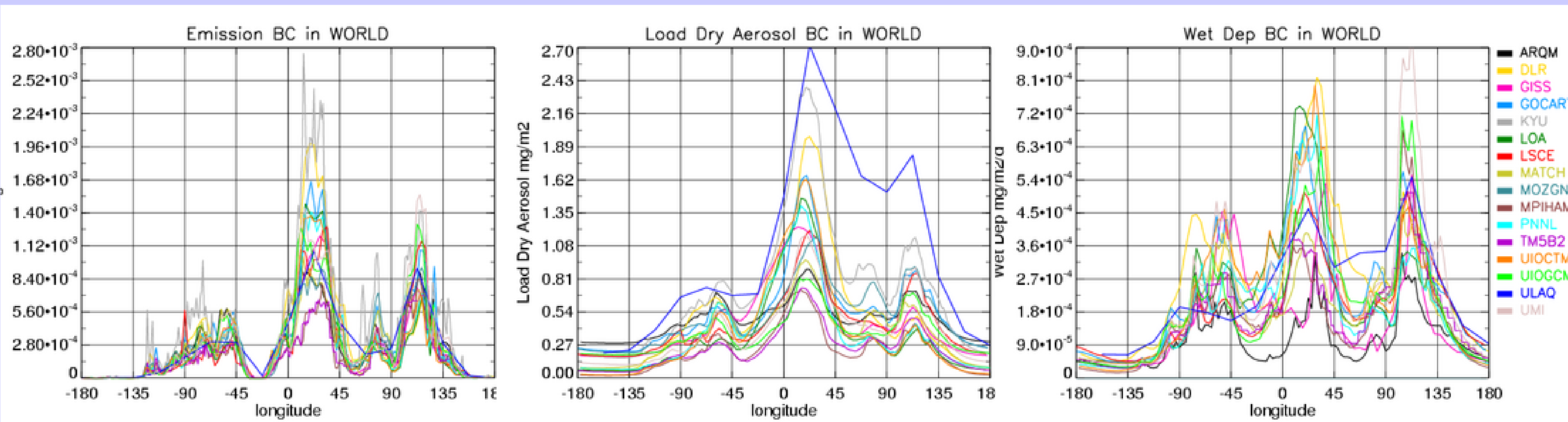
Spatial distribution SO4



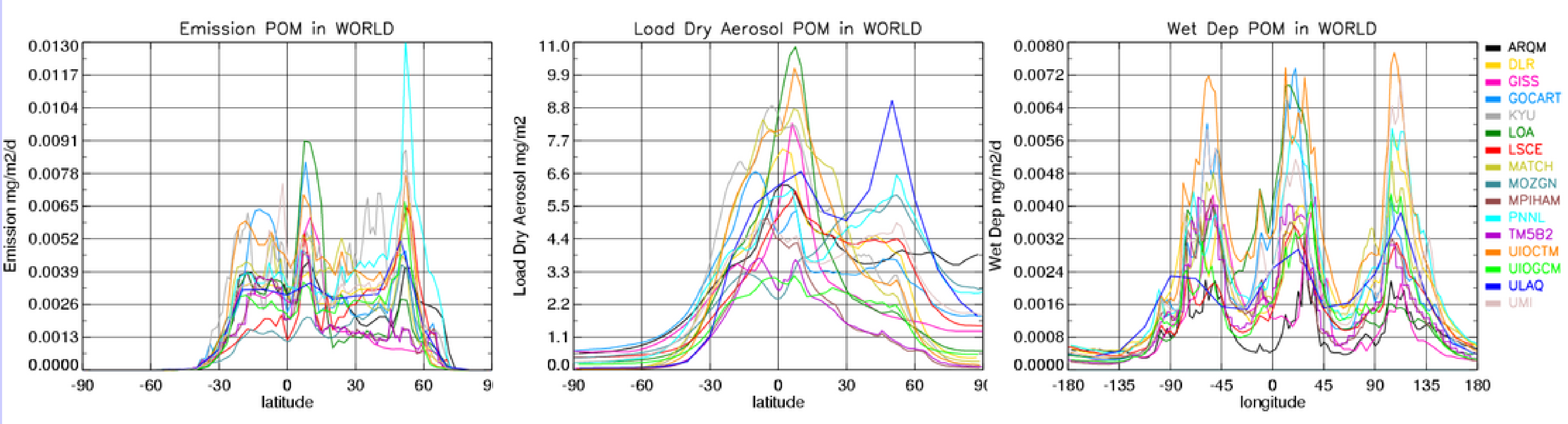
Lower agreement on emissions and load: spatial distr. + total

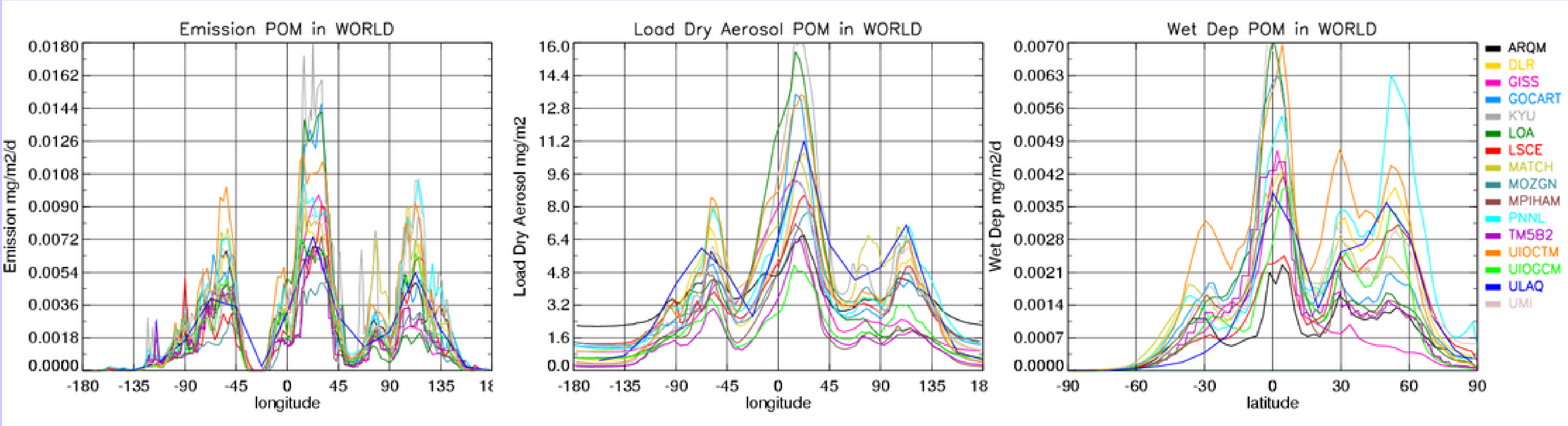
Spatial distribution BC





Spatial distribution POM

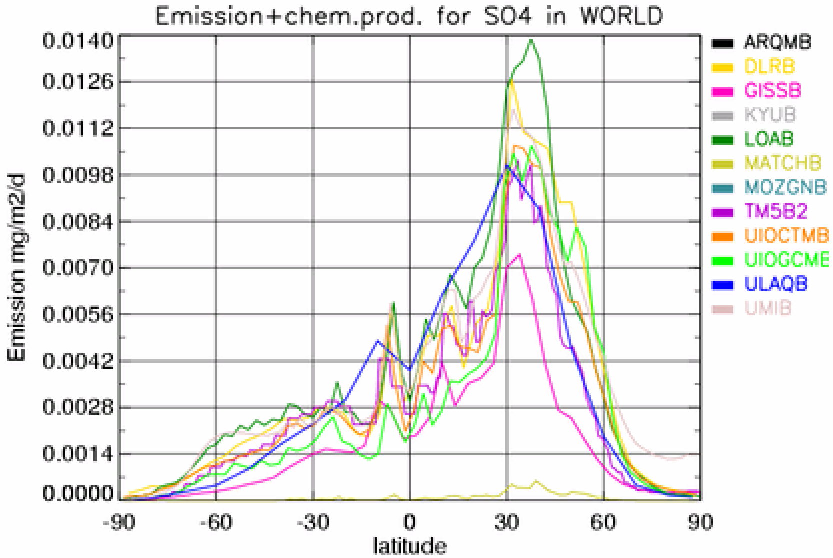


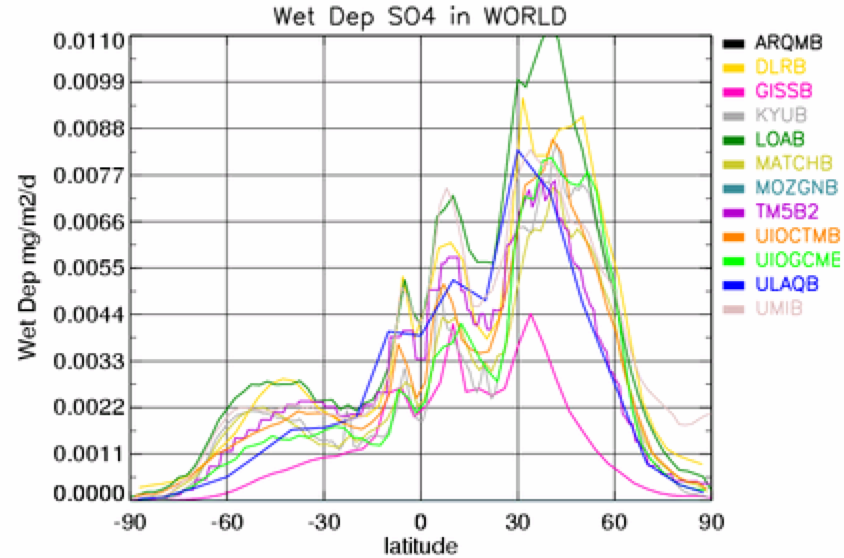


Conclusions

- Model diversities and averages for global annual means in Exp A established (submitted to ACP)
- Exp B harmonized emissions and initial particle sizes:
  - do not lead to higher agreement in loads,
  - increase model agreement on removal rates of coarse aerosols (outliers removed),
  - minor influence on fine aerosols and on aerosol dispersal.
- SS: Load and sink processes are spatially consistent.
- DU: Model diversity in load is due to wet dep.

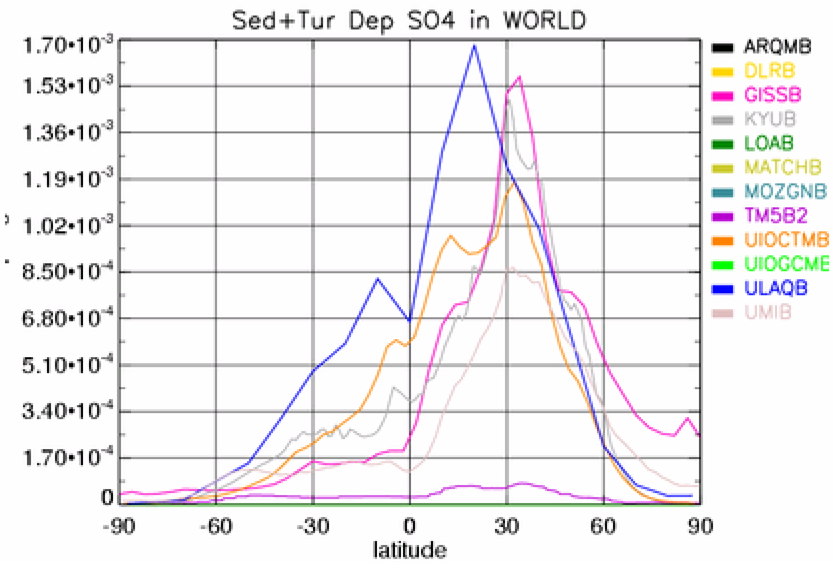
urück Adresse http://nansen.ipsl.jussieu.fr/cgi-bin/AEROCOM/surfobs/synthesis_annua Datei Bearbeiten Ansicht Favoriten Extras ?

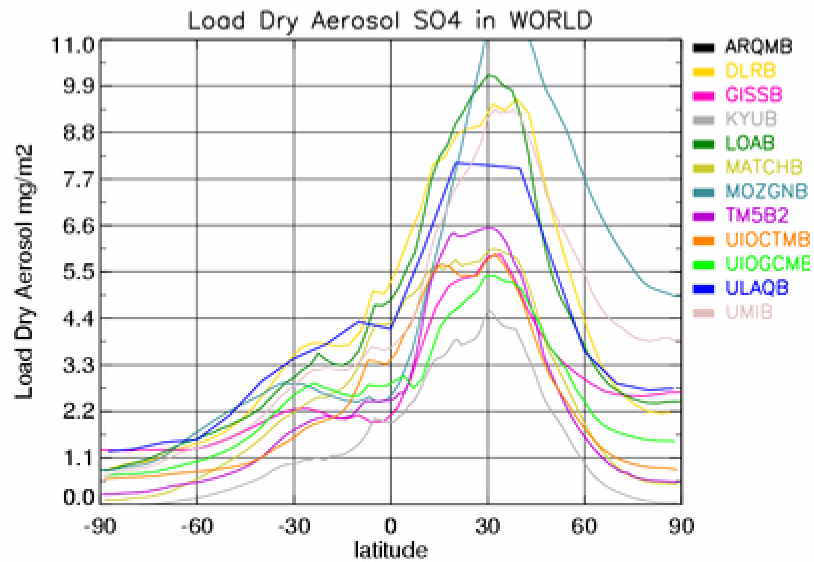




onal AEROCOMB SO4 SedTur
ORLD an2000

Zonal AEROCOMB SO4 Load
WORLD an2000





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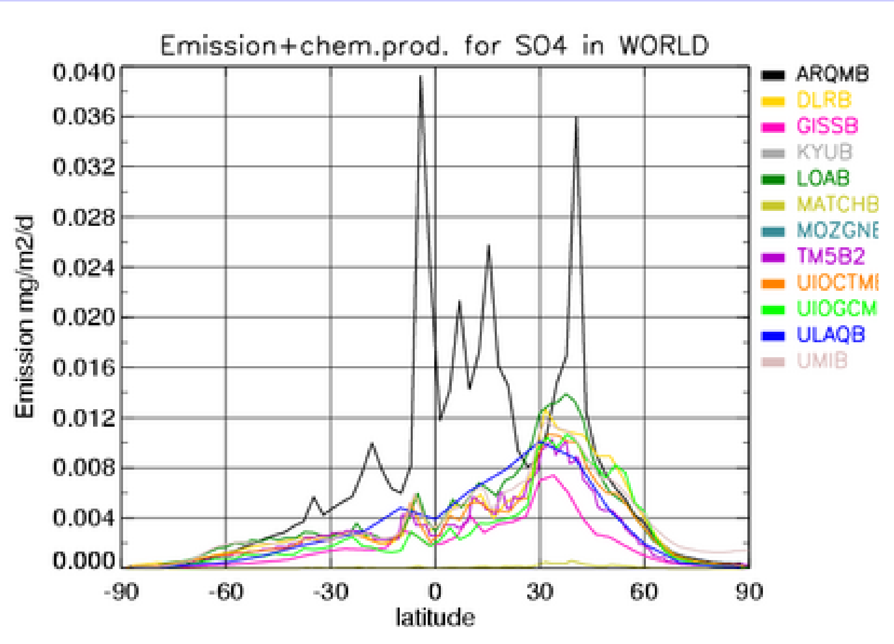
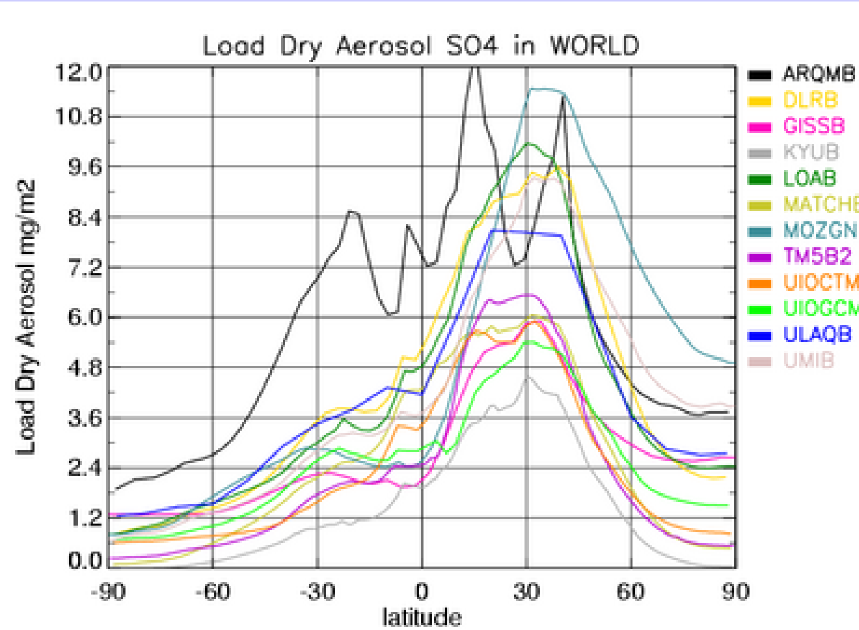
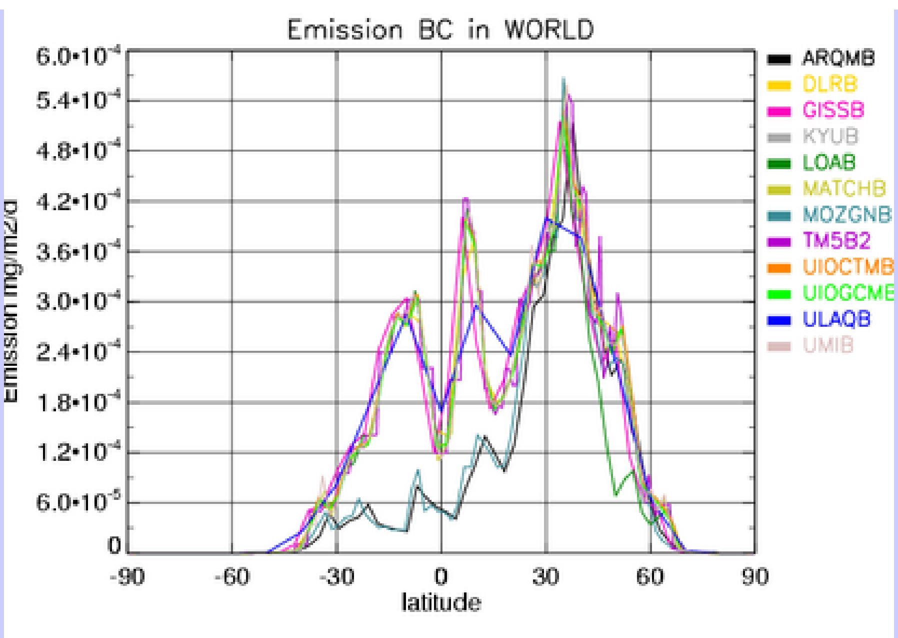
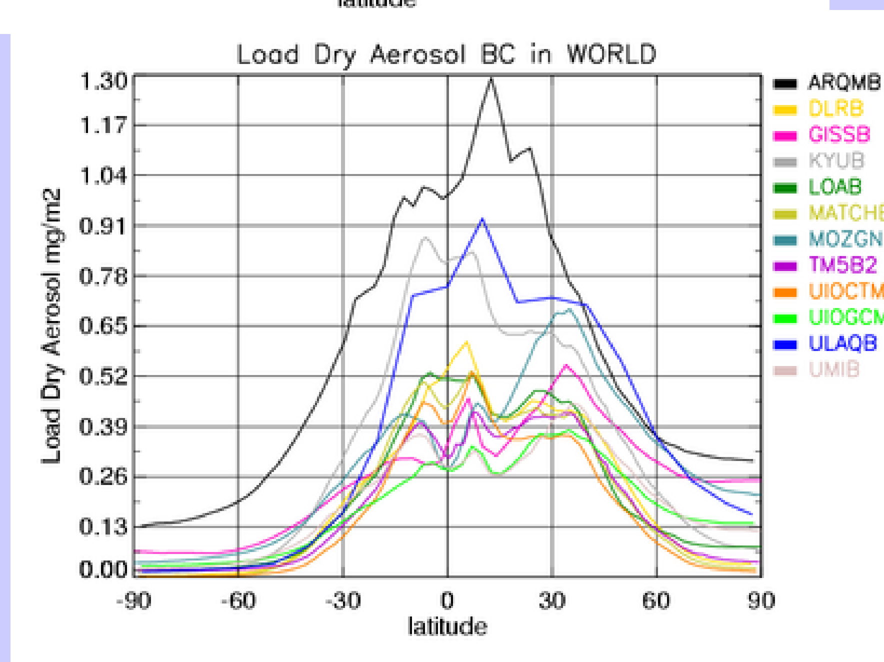
Zonal profiles: emissions and load in Exp A and B

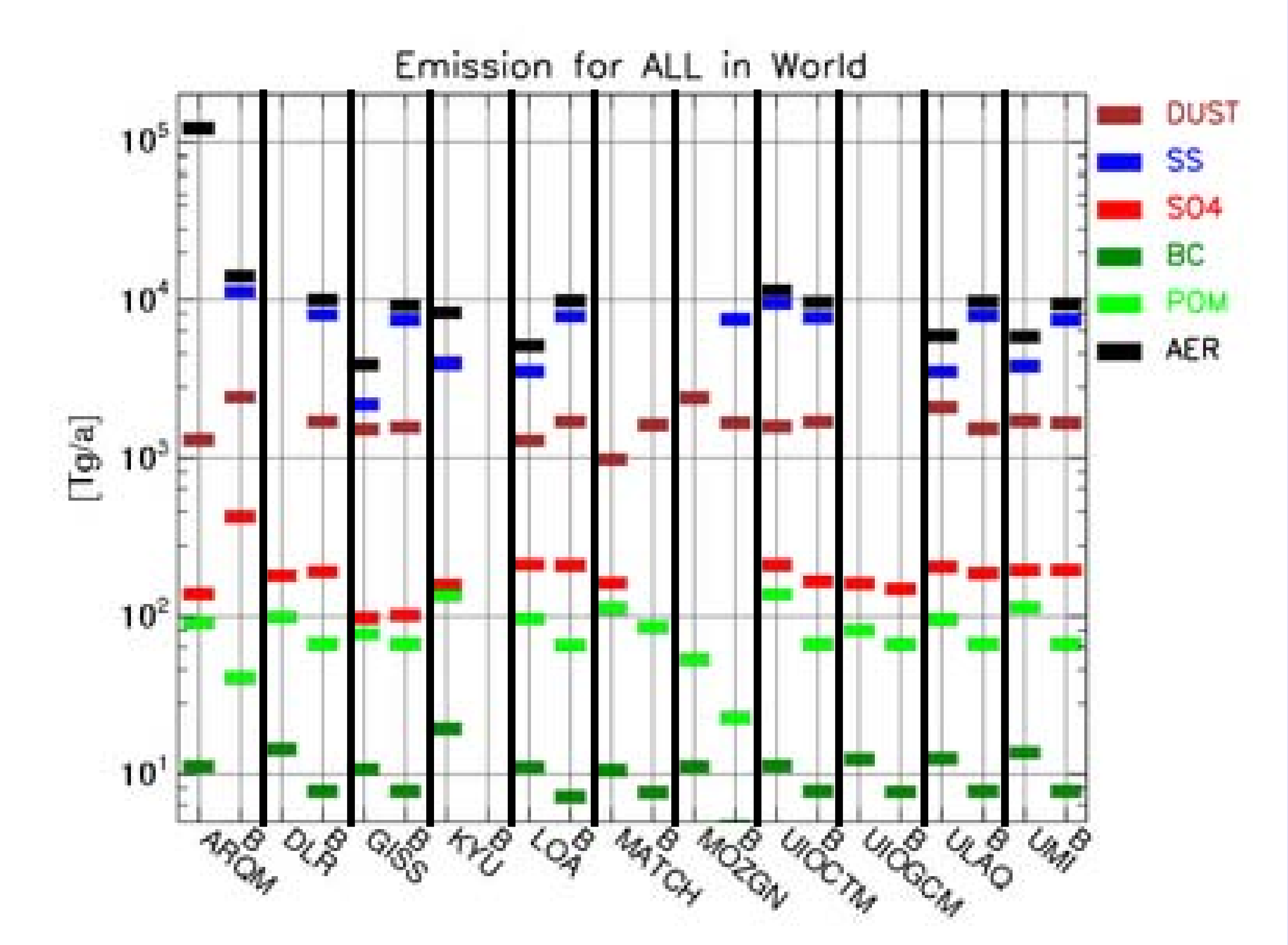




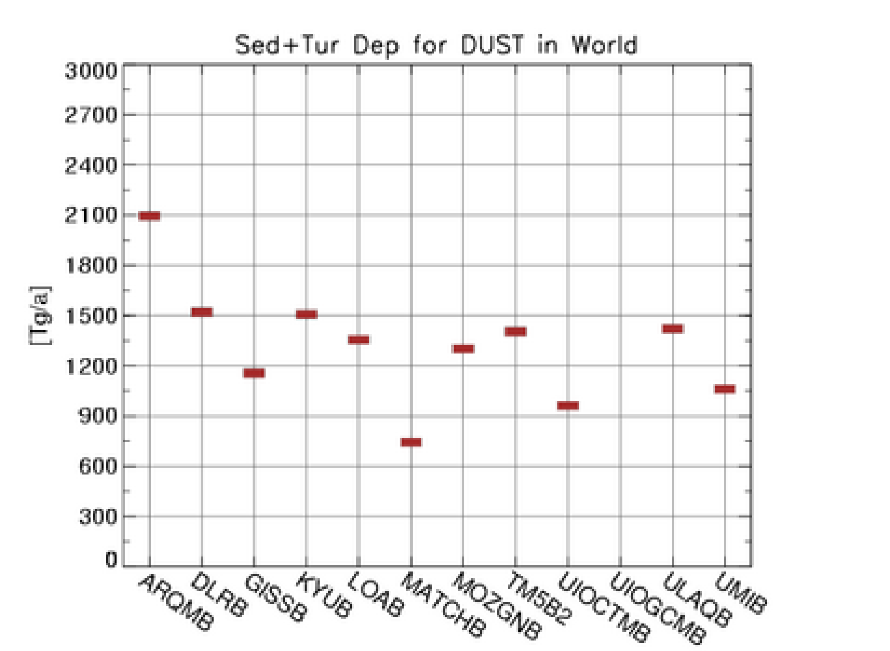


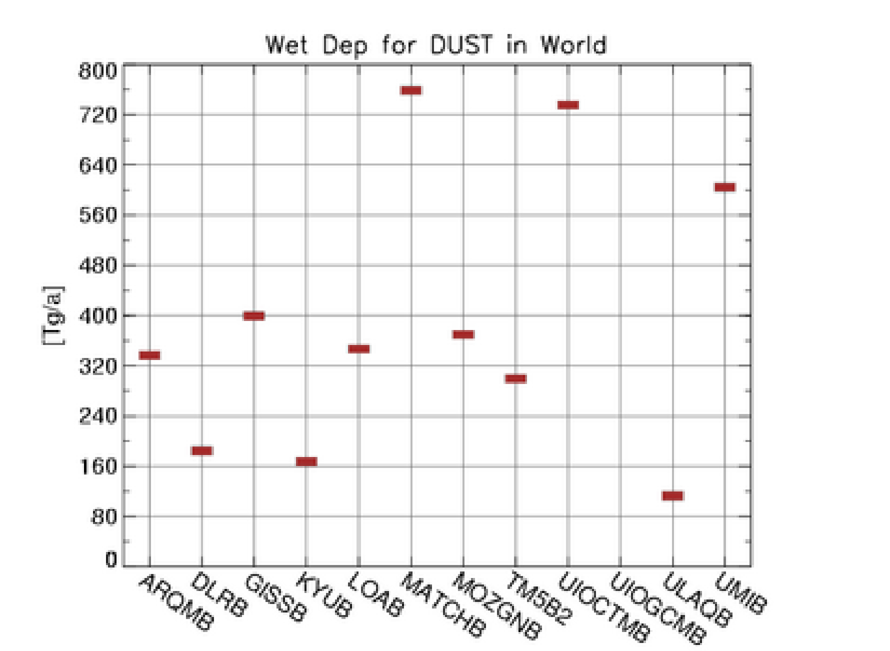


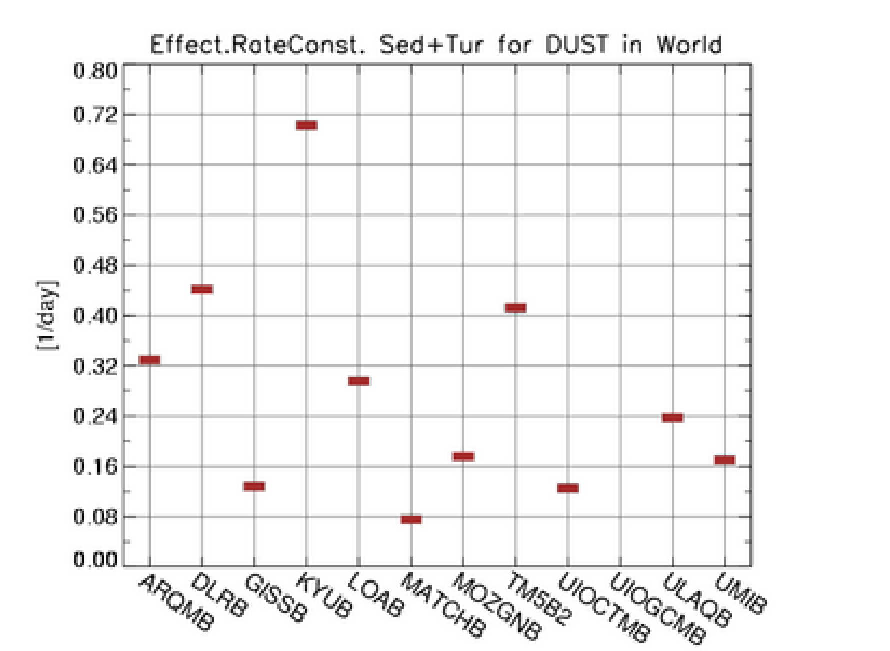
Emission comparison Exp A and B

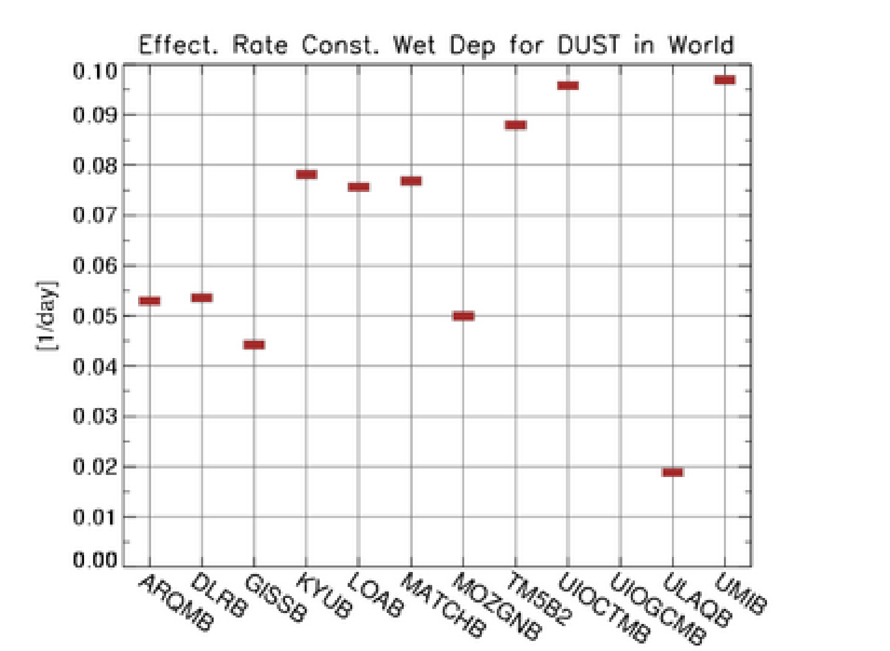


Exp B: BC and POM smaller

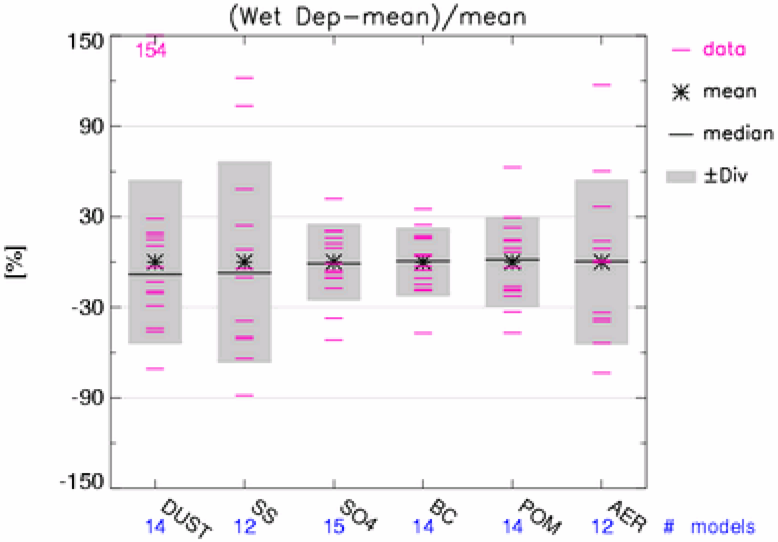

Sed+Tur Dep for DUST in World
[Tg/a]
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
ARQMB
DLRB
GISSB
KYUB
LOAB
MATCHB
MOZGNB
TM5B2
UIOCTMB
UIOGCMB
ULAQB
UMIB


Wet Dep for DUST in World
[Tg/a]
800
720
640
560
480
400
320
240
160
80
0
ARQMB
DLRB
GISSB
KYUB
LOAB
MATCHB
MOZGNB
TM5B2
UIOCTMB
UIOGCMB
ULAQB
UMIB

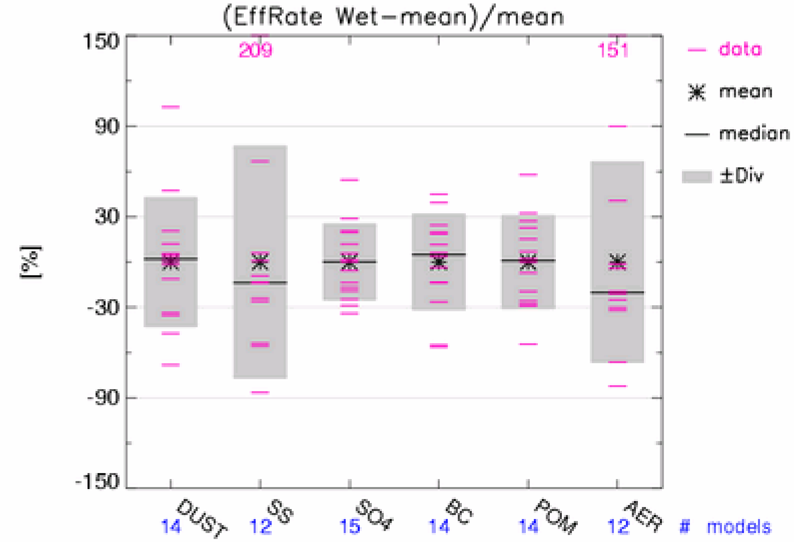

Effect.RateConst. Sed+Tur for DUST in World
[1/day]
0.80
0.72
0.64
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0.00
ARQMB
DLRB
GISSB
KYUB
LOAB
MATCHB
MOZGNB
TM5B2
UIOCTMB
UIOGCMB
ULAQB
UMIB


Effect. Rate Const. Wet Dep for DUST in World
[1/day]
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
ARQMB
DLRB
GISSB
KYUB
LOAB
MATCHB
MOZGNB
TM5B2
UIOCTMB
UIOGCMB
ULAQB
UMIB

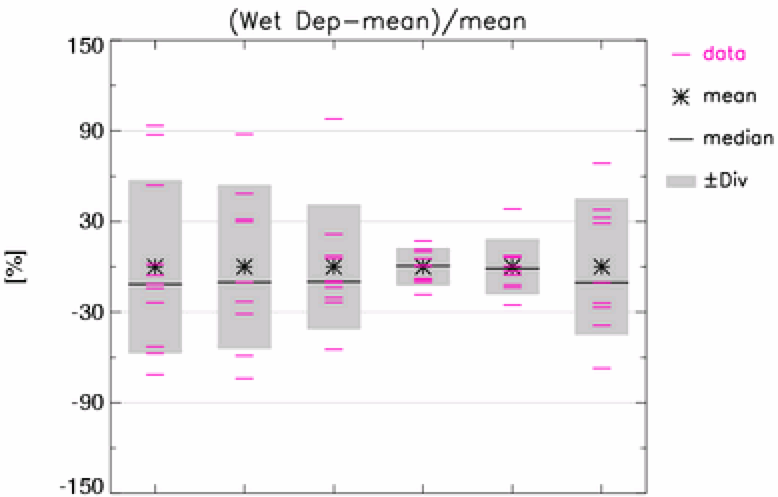
atStdDev | AEROCOMA | ALL | Wet | ORLD | an2000



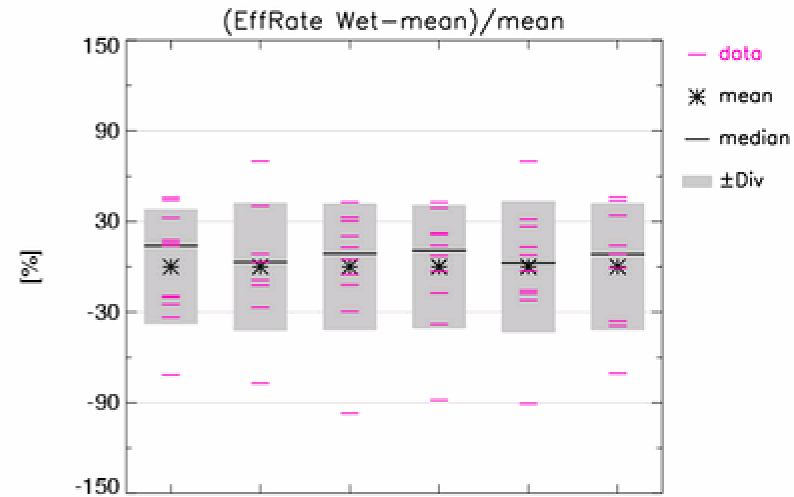
StatStdDev | AEROCOMA | ALL | Kwet | WORLD | an2000



atStdDev | AEROCOMB | ALL | Wet | ORLD | an2000

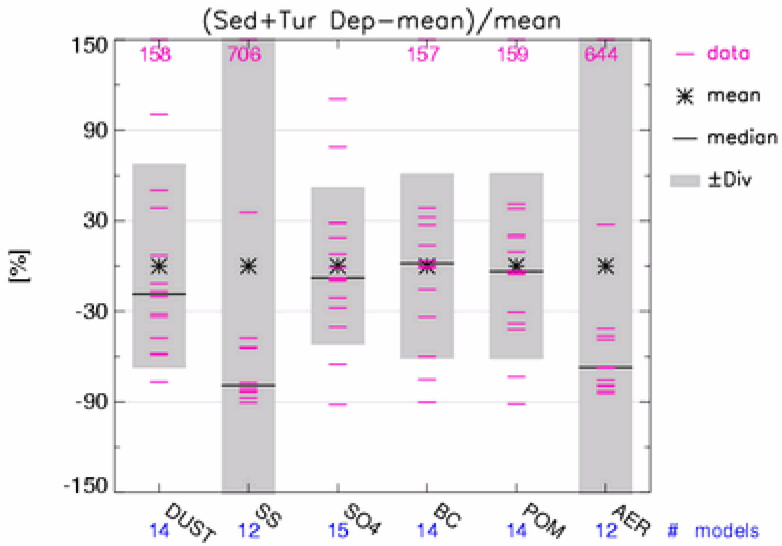


StatStdDev | AEROCOMB | ALL | Kwet | WORLD | an2000

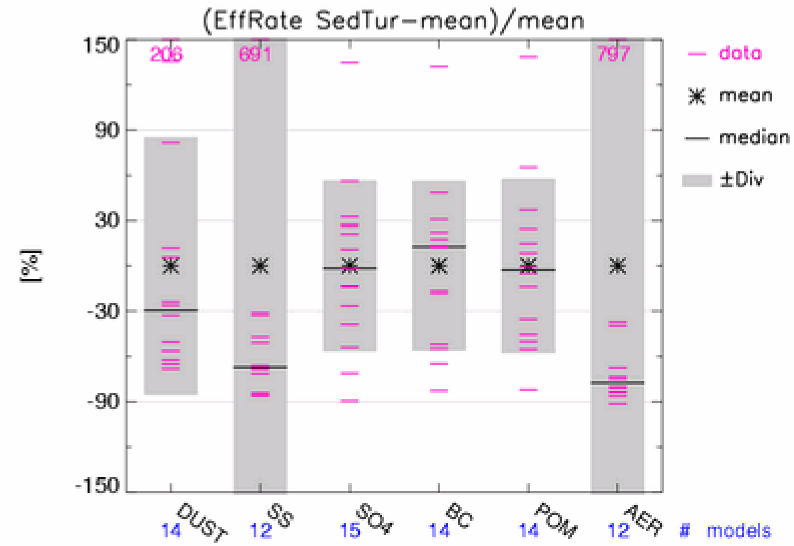


urück Adresse http://nansen.ipsl.jussieu.fr/cgi-bin/AEROCOM/surfobs/synthesis_annua Datei Bearbeiten Ansicht Favoriten Extras ?

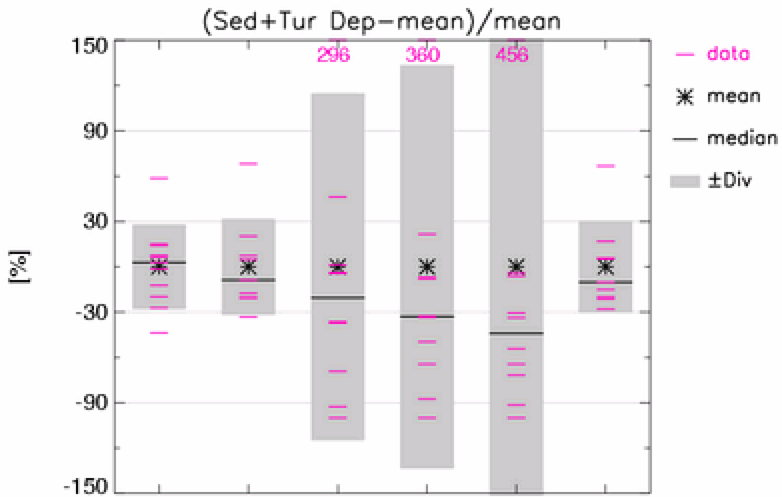
atStdDev | AEROCOMA | ALL | SedTur | ORLD | an2000



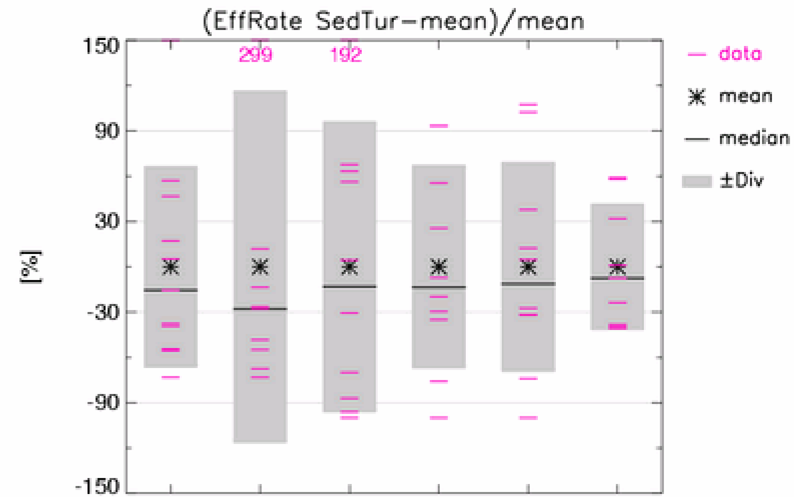
StatStdDev | AEROCOMA | ALL | Ksedtur | WORLD | an2000



atStdDev | AEROCOMB | ALL | SedTur | ORLD | an2000



StatStdDev | AEROCOMB | ALL | Ksedtur | WORLD | an2000



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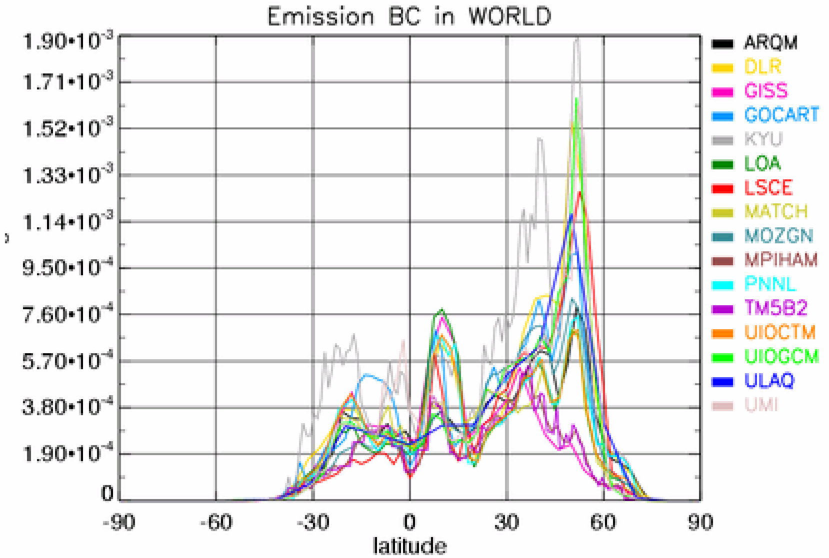
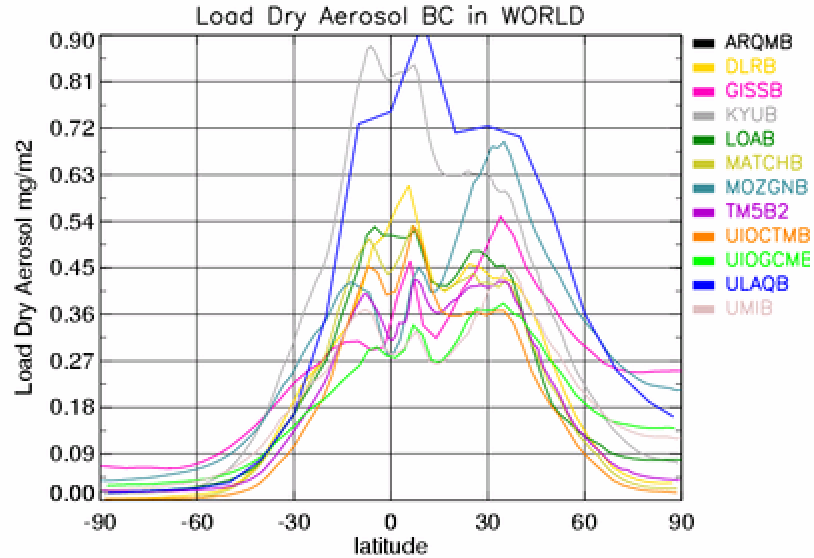
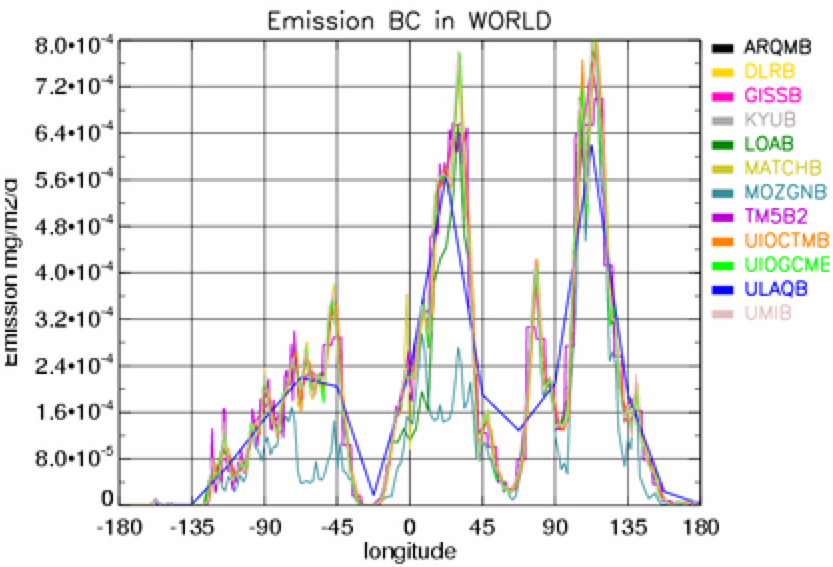
urück Adresse http://nansen.ipsl.jussieu.fr/cgi-bin/AEROCOM/surfobs/synthesis_annua Datei Bearbeiten Ansicht Favoriten Extras ?

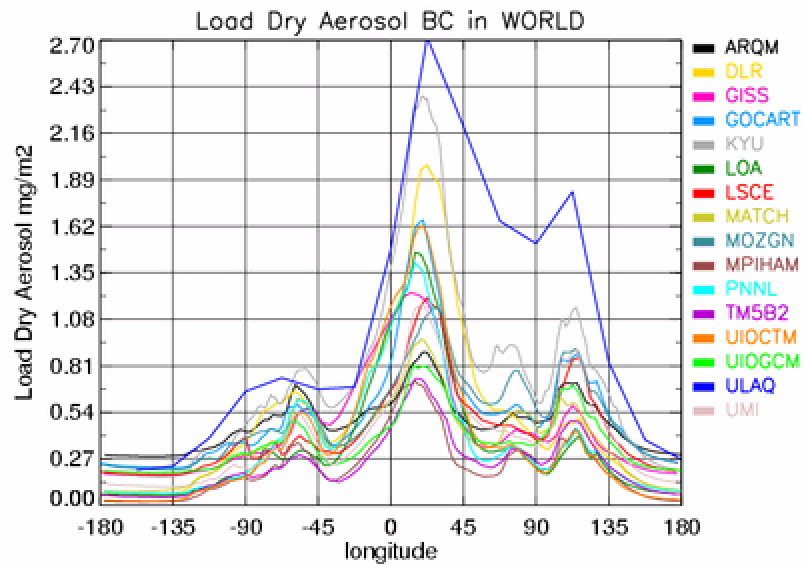




erid | AEROCOMB | BC | Emi
ORLD | an2000

Merid | AEROCOMA | BC | Load
WORLD | an2000





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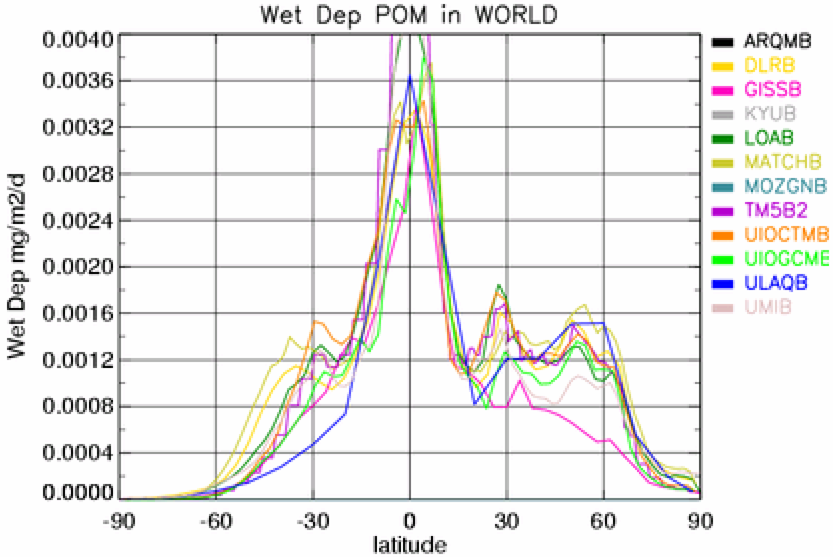
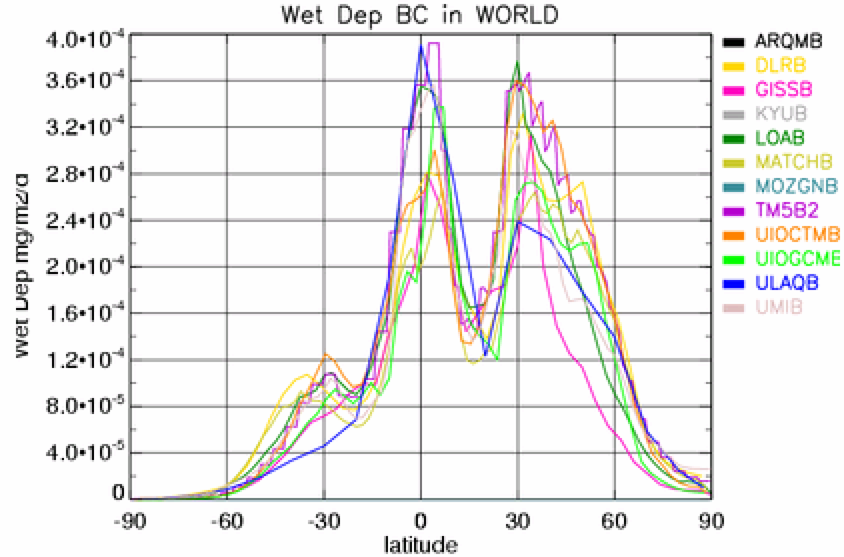


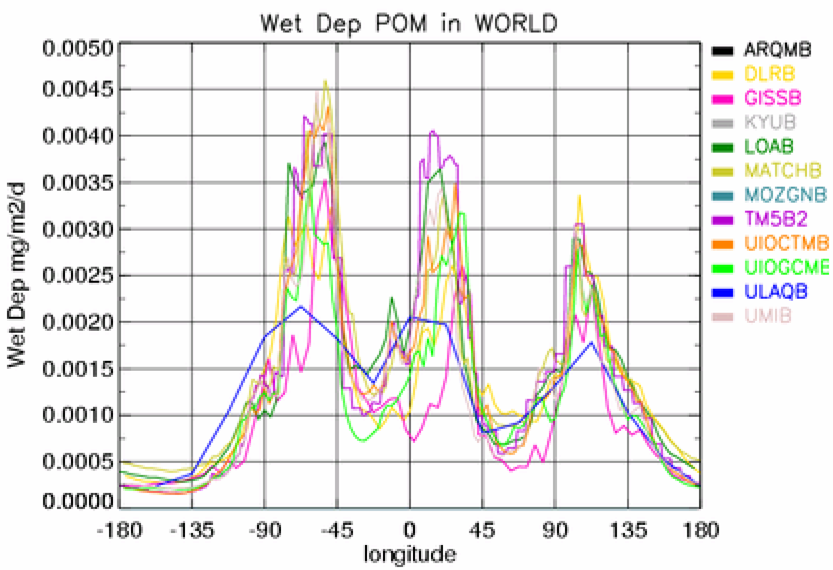


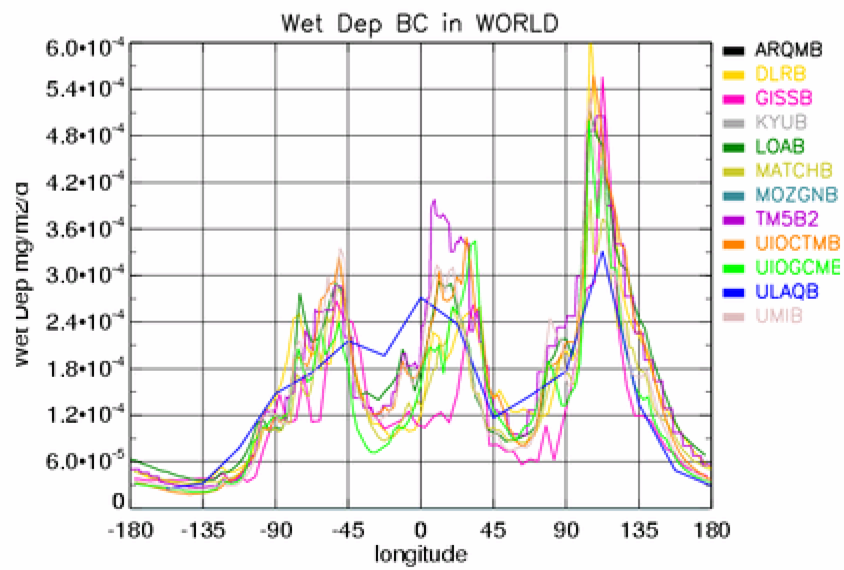
erid | AEROCOMB | POM | Wet

ORLD | an2000

Merid | AEROCOMB | BC | Wet

WORLD | an2000





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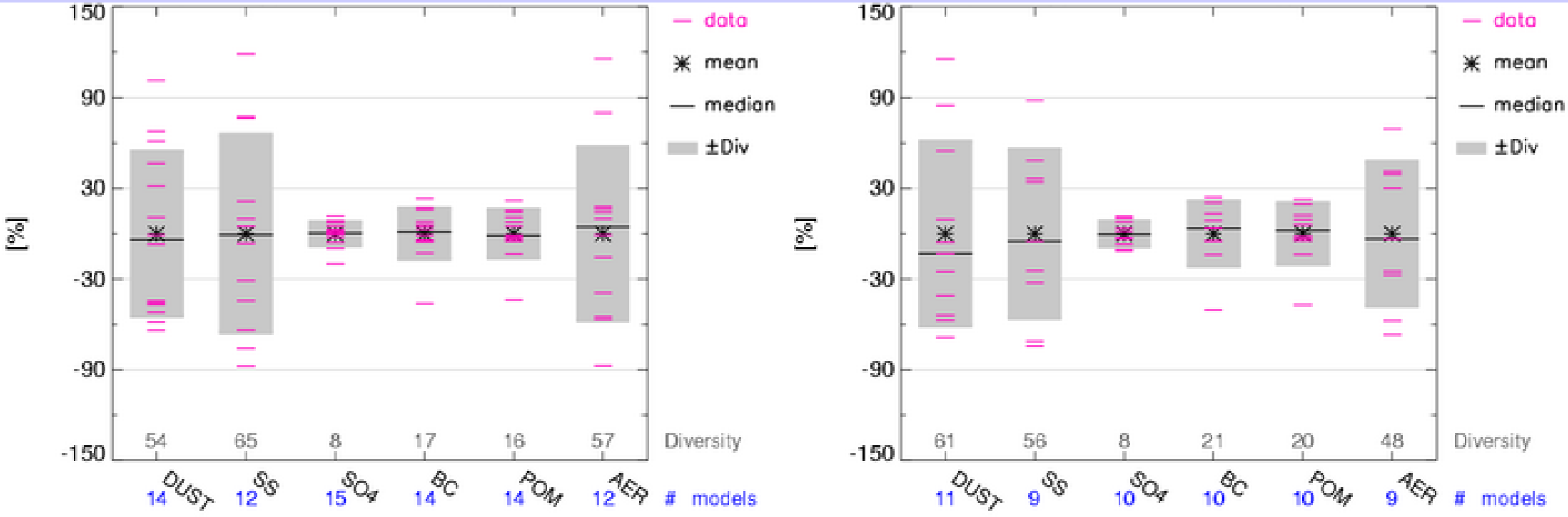
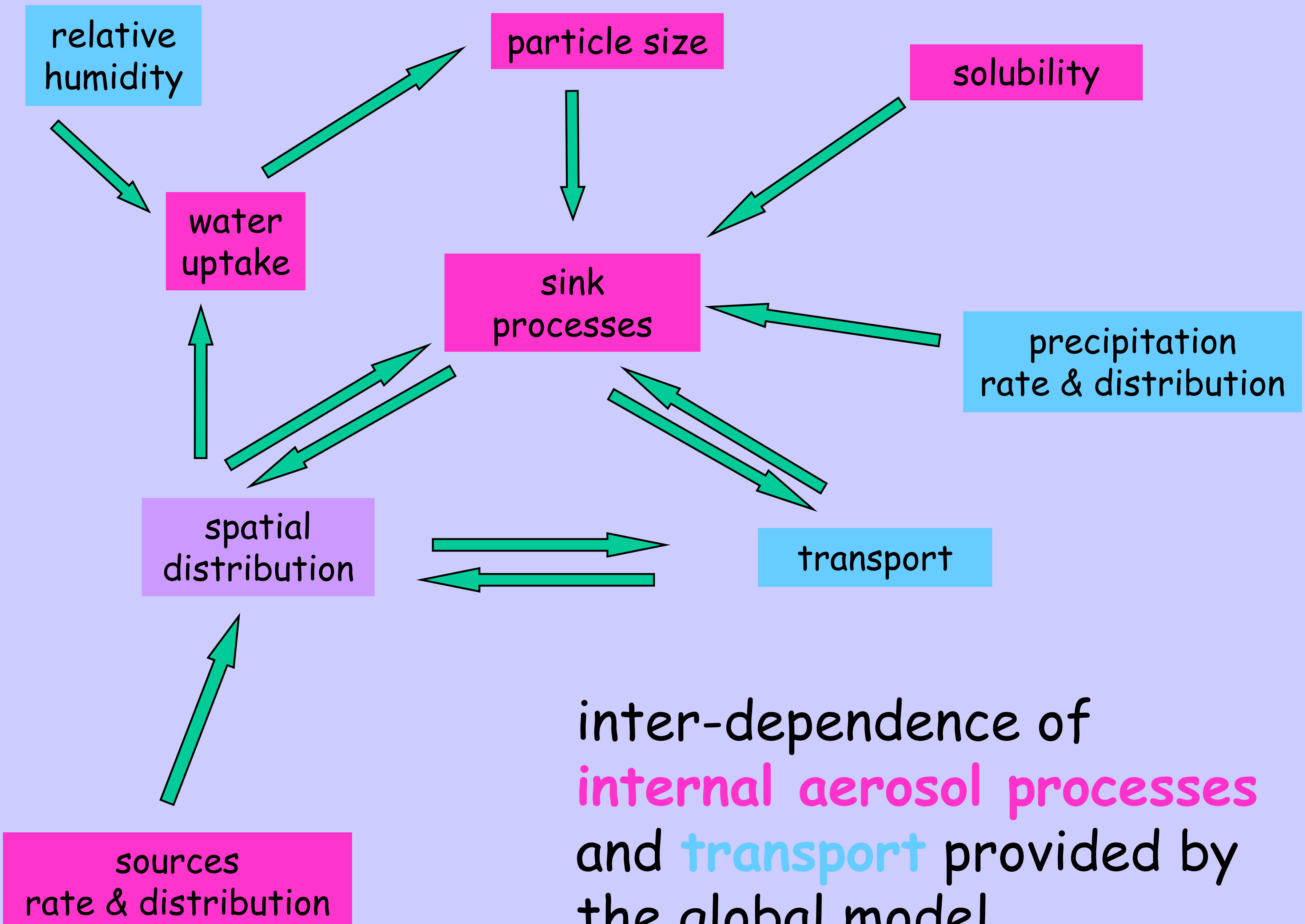
Contribution of wet deposition to total deposition



The aerosol life cycle

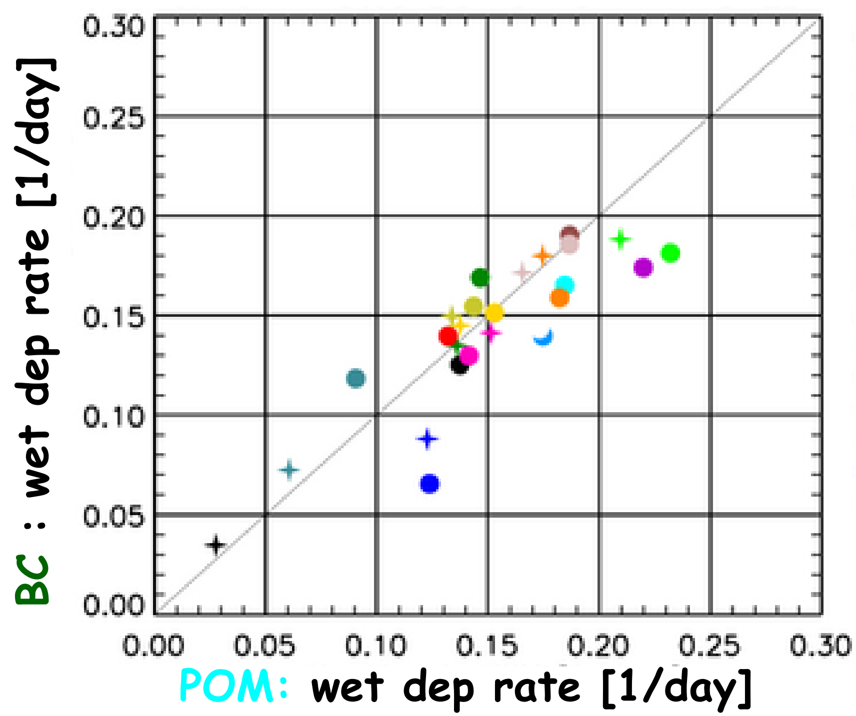


inter-dependence of **internal aerosol processes** and **transport** provided by the global model

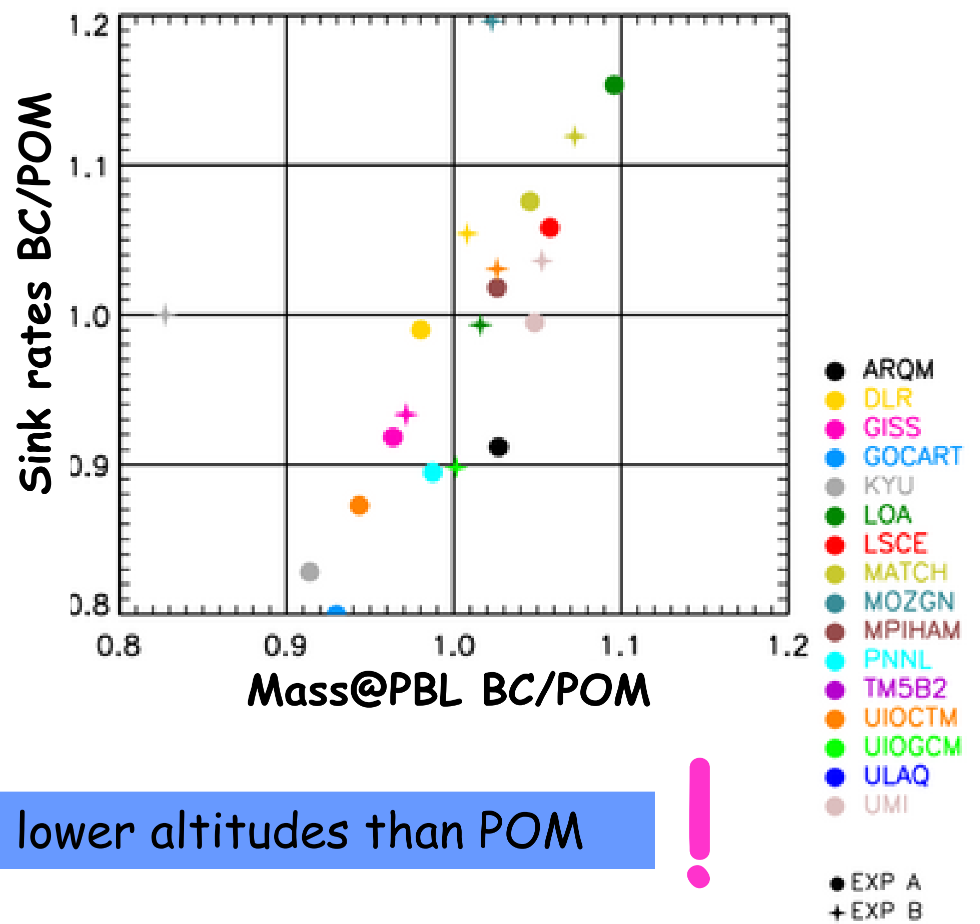
Removal rate vs vertical dispersal

Faster sink rate for BC than for POM ?

Wet dep rate BC vs POM



Ratios BC/POM:
sink rates vs mass in PBL



If BC at lower altitudes than POM !